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WASTE OIL STUDY

PRELIMINARY REPORT TO THE CONGRESS

ENVIRONMENTAL PROTECTION AGENCY

APRIL 1973

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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Table of Contents

	Page
Summary	1
Introduction	2
Generation of Waste Oil	4
A. Quantities of Waste Oil Generated	4
1. Automotive Oil	4
2. Industrial Oils	8
B. Physical and Chemical Chracteristics of Waste Oils	14
1. Automotive lubricants	14
2. Metalworking lubricants	15
3. Plant and Animal Oils	20
4. Petroleum refining operation wastes	21
C. Present Methods of Collection and Disposal	23
1. Methods of Collection	23
2. Disposal and Recovery of Waste Oils	23
a. Re-Refining	23
b. Use as a Fuel Oil	32
c. Use in Land Application	32
d. Other Disposal Methods	33
D. Biological Effects of Waste Oil	34
1. Origins of Oil Pollution	35
2. Toxic Effects of Oil	39
3. Effects of Treated Oils	43
4. Carcinogenic Effects	44
5. Public Water Supply Effects	44
6. Waterfowl and Wildlife Effects	45
7. Pollution in Media Other Than Water	46
8. Recommendations	46
E. Economic and Legal Aspects of Waste Oil Policy	48
F. Additional Information Being Developed	51
References	53

List of Tables & Figures

Tables

		Page
1.	National Oil Sales Volumes	5
2.	Trends in Motor Oil Consumption	7
3.	Annual Per Capita Oil Use in United States	12
4.	Typical Waste Automotive Oil Composition	16
5.	Used Automotive Lubricating Oils-Trace Metals Content	17
6.	Used Automotive Lubricating Oils-Selected Properties	18
7.	Oil-Based Metal Working Lubricants	19
8.	Metal Content of Waste Oil Re-Refining Oil Sludge	22
9.	Data Survey of Selected Oil Re-Refiners	24

Figures

1.	Virgin Lube Oil Sales in the United States	9
2.	Waste Lube Oils Generated in the United States	10
3.	Flow Scheme for Acid-Clay Type Re-Refining Process	26
4.	Flow Scheme - IFP Propane Classification Process	28
5.	National Oil Recovery Corporation Project Flow Sheet	29
6.	Solvent Extraction - Waste Oil Treatment	30
7.	Waste Oil Hydrotreating - Distillation Process	31

SUMMARY

Section 104(m)(2) of the Water Pollution Control Act Amendments of 1972 required the Administrator of the Environmental Protection Agency to study the problem of the disposal of waste oils and their effect on the environment. This report is submitted in fulfillment of the requirement for a preliminary report within six months after enactment of the legislation. The report emphasizes the information required in Section 104(m)(1)(A) and presents the data currently available which are applicable to Sections (B) and (C).

The report presents the information available to date on the quantities of waste oils produced and their physical and chemical properties. A review of the current disposal and re-refining processes is presented together with a brief evaluation of the current state-of-the-art and anticipated technological improvements. Information on the economic structure of the waste oil business is also reported. Due to the limited time available for the preparation of this report, the data on chronic long-term ecological effects of waste oil disposal are not available. Because of the lack of information available in the literature and the necessity for time to determine long-term biological effects, it is not possible to report on such effects at this time.

It should be noted that much of the information presented is based on limited data available in the literature. Additional studies are being carried out by this Agency and others. The results of this on-going work will be included in the final report due to be issued in April 1974. In addition, any recommendations for legislation or institutional changes will be withheld until that time when the results of these on-going or anticipated studies are available.

INTRODUCTION

The Congress, in Public Law 92-500, "Federal Water Pollution Control Act Amendments of 1972," recognized that waste oil is an environmental hazard. In Section 104(m), Congress requires the Administrator of the Environmental Protection Agency to conduct studies leading to the prevention of the degradation of the environment from the disposal of waste oil. The Administrator was further required to report preliminary results of such studies to Congress by April 15, 1973. This report details the preliminary results of the studies undertaken and presents information on the studies to be undertaken as a partial fulfillment to this requirement.

Oil enters the environment ranging in forms from raw crude to highly refined machine oil. The routes of entry are as varied as the products. These include continuous discharges, illegal dumping, accidental spills and overboard discharges from vessels such as contaminated ballast and tank washings. At the present time it is estimated that approximately 1.5 billion gallons of spent lube oil and greases from vehicle crankcases and industrial plants are produced each year. This volume is expected to grow at a rate of about 2% per annum. About half of this waste oil is disposed of with no assurances made to prevent subsequent pollution of ground and surface waters. The uncontrolled disposal of any oil to the environment can cause environmental damage. Because of its heavy metals content, waste crankcase oil poses the possibility of a serious threat to all living resources. Waste oil is currently disposed of in a number of ways. No one use is environmentally superior in every situation. The local conditions, as well as types of oil to be handled, must be considered when determining the optimum solution. This situation is further complicated because little or no data are available on long term ecological effects of waste oil. These effects can only be tenuously extrapolated from crude and fuel oil data. Generation and disposal patterns are only now being studied in detail sufficient to properly define the problem.

About 2.3 billion gallons of lubricating oils and grease are sold for use in the United States each year. Of this 2.3 billion gallons, about 1.5 billion gallons ends up as waste lube oil. Historically, much of this waste oil has been used for dust prevention on roads. This use is going out of fashion and is environmentally unacceptable. Very little (approximately ten percent) of the 1 billion gallons of motor waste oil is reprocessed. Some is currently blended into fuel oils and most of it is currently dumped either on land or into watercourses. A preliminary analysis of the ecological effects of such dumping is included in this report and further work in this area is planned.

Industrial waste oils and waste fuel oils can be reprocessed and are usually easier to recover because of the concentration at the source. However, a great deal of these materials are not introduced into the reuse cycle. This report presents a brief analysis of the current waste oil status and composition. A summary review of the current practices of re-refiners is presented together with a brief evaluation of the current state-of-the-art and anticipated developments.

At the present time little can be stated in respect to the biological impact, i.e., direct or community alteration by sublethal responses within the

populations. However, it is these biological impact manifestations that must be addressed for each of the various components of waste oil within a comprehensive investigation of the effects on the biotic components of our environment. Studies now underway or planned for the near future will provide some of the much needed information on the effects of waste oil disposal practices. These will be included in the final report next year. A very brief analysis of the biological effects as we can determine them on extremely limited data is presented. Work is being carried out by other agencies on the waste oil problem and this is briefly discussed. The report also presents a discussion of anticipated studies to be carried out and reported on in detail in the final report.

Generation of Waste Oil

Waste oil, as defined in this report, is an oil which has served its useful purpose and no longer has the chemical and/or physical properties required. In addition, some oily non-useable by-product materials resulting from manufacturing operations are included in this category. This section of the report is concerned with how much and what kind of oil becomes waste oil. The quantities and sources of waste oil produced are identified to the extent that existing data permits.

A Quantities of Waste Oil Generated

1. National Estimates

For the year of 1969, a net amount of 2.29 billion gallons of various lubricant materials were sold within the United States. On the basis of linear extrapolation using the period of 1967-1971 to determine the rate of change, the projected total national oil sales for 1975 is estimated to be 2.42 billion gallons.

Approximately 50 percent of this amount is consumed in the various applications of these materials (1). The balance of this material, 1.1 billion gallons, is either available for recycling into various oil products or requires disposal. The difference between the total lube oil sold and the total waste oil produced is the consumption by the machine itself (burning or leakage), discarding of oils in junked machinery and autos, and similar factors.

The amount and type of oil that remains after use varies with the type of oil. The amounts of various types of oils sold nationally are shown in Table 1. Two broad categories of waste oil can be identified: automotive and industrial oils. They will be discussed more fully below.

Automotive Oil

Automotive oils include all crankcase oils, transmission fluid, differential gear lubricants, hydraulic oil, and small quantities of solvents frequently used in automotive installations. Sales of automotive oils represents over 50 percent of total sales.

(a) Crankcase Oil

It is estimated that 66 percent of automotive crankcase oil evantually is left as waste.

It appears from inspection of the data in Table 1 that there is an increasing trend in the use of lubricants. On the basis that 66 percent

TABLE 1

NATIONAL OIL SALES VOLUMES

Type	%Change* per year	Year (Million Gallons) 1967	1969	1971	1975**
Auto	+ 0.9	1,032	1,051	1,071	1,107
Aviation	- 9.9	13.1	9.9	8.4	5.9
Industrial Lube Oil	+ 1.17	699.1	781.2	726	751
Other Industrial Oils	+ 5.5	315.0	342.0	388	450
Auto & Aviation Grease[a])	- 1.7	52.4	53.2	49.8	47.3
Industrial Grease[a])	- 0.6	57.2	55.1	55.7	54.7
TOTAL	+ 1.49	2,168.8	2,291.4	2,298.9	2,415.9

*Based on 1967-71 sales (average % change per reporting period).

**Projected

a)Volume based on 9 lbs/gal. density

References: (1), (3)

of new automotive lube oil becomes waste automotive lube oil, the national amounts of waste lube oil would be approximately 680 million gallons in 1967, 690 million gallons in 1969, and a projected value of 730 million gallons in 1975. However, the decreasing consumption of engine oil relative to fuel oil and the specific consumption of oil per mile travelled has been noted by several observers (2&3). Table 2 shows the variation in oil consumption over the period 1950 to 1969. Between the period 1950 to 1955 a decrease of 10-1/2 percent in oil consumption per mile was realized. In subsequent time periods, this decrease changes to 25 percent for the period 1955 to 1960; 30.5 percent for the period 1960 to 1965; and 28.5 percent for the period 1965 through 1969. This drop in consumption can be generally attributed to increased time between oil changes.

Two trend indicators which influence projections of motor oil consumption should be explored in more detail. The first of these is the ratio of fuel to motor oil consumption. In 1969, the total number of registered vehicles in the U.S. was approximately 107 million units including buses, trucks, and passenger vehicles. These vehicles required 88.1 billion gallons of motor fuel; the ratio of fuel to oil for passenger cars is cited as approximately 227 gallons of gasoline per gallon of oil for passenger cars. On an overall basis, taking all automotive lubricant oils and comparing them with the total number of vehicles of all types in the United States, the ratio of fuel to motor oil is approximately 81 gallons of fuel to one gallon of motor oil lubricant. The discrepancy between the ratios of 81 and 227 gallons of gasoline per gallon of oil previously cited is apparently due to the many stationary internal combustion engines, marine engines, and the many two- and four-cycle low horsepower portable engines currently in use in the United States. In 1969, about 1 billion gallons of motor oils were sold. Thus, approximately 10 gallons of lubricant oil were sold for each vehicle registered in the United States.

The second major indicator is the mileage factor: A strict evaluation of the curves for automobile crankcase drainage coupled with the decrease in consumption per 1000 miles driven would seem to indicate that the quantities of oil that will be available in the years 1971 through 1975 will decline or at best stay at the levels noted for 1969 and 1970. However, if the analyses are divided into several elements which include the impact of other factors, the long-term trend in automotive oil sales will increase. During the 1960's, automobile sales increased and cars were being driven more miles per year. This would have shown an increase in the quantity of oil sold if the overall composition of the oil had not been dramatically changed.

In the late 1950's oil was drained about every 2000 miles, oil in the late 1960's was drained between 4000 and 6000 miles. The automobile manufacturers have since reversed their trend for increased mileage between oil changes. They now suggest that oil be changed every 3000 to 4000 miles and filters every second oil change. It is felt that oil life has somewhat stabilized at this latter figure and that oil sales will parallel automobile

TABLE 2

TRENDS IN MOTOR OIL CONSUMPTION (1)*

YEAR	Gallons Oil per 100 Gallons Fuel	Quarts Oil per 1000 Miles
1950	1.44	3.81
1955	1.25	3.42
1960	0.91	2.56
1965	0.64	1.78
1966	0.60	1.68
1967	0.54	1.52
1968	0.49	1.40
1969	0.44	1.27

* Includes all cars and trucks designed for highway use.

sales quite closely.

Accordingly, two projections were made for auto lubes: one taking into consideration all the data and a second (more conservative) placing a much greater weight on oil sales during the previous three years. As the latter produces a higher value for crankcase drainage, it will be utilized to project the quantities of oils expected in the future.

(b) Automotive Brake Fluid

Statistics (2) show that approximately 10 million gallons per year of automotive brake fluid have been compounded and sold nationally over the period 1966 through 1969. A portion of this material is used in new applications while the balance is for replacement purposes. On the basis of an estimated 10 million new vehicles per year (2) and an assumed value of 0.1 gallon of hydraulic brake fluid per vehicle on the average, the balance yields an estimated amount of replacement brake fluid of 1 million gallons per year. This would be the maximum expected value of this category which might be recovered in a given year providing adequate measures were taken to collect this material.

Industrial Oils (Ballast and Bilge Wastes not included)

Industrial Lube Oils and Other Industrial Oils

Similar calculations may be made for the category comprising industrial lube oils and other industrial oils. As previously described, this category yielded 29.6 percent waste material. On this basis, 300 million gallons of waste industrial oil was produced in 1967, 330 million gallons in 1969, and 355 million gallons projected for 1975.

Grease

The consumption of "grease" remains relatively constant even in the face of greater auto and lube oil sales. This can be explained by the expanded use of non-lubricating fittings in rotating equipment.

National Trends

A graphic presentation of the total growth in waste oil, including both industrial and automotive oils, is shown in Figures 1 and 2. These composite curves are based on linear projections using the data reported for the periods from 1967 through 1971.

2. Regional Distribution of Waste Oil

Large variances in the generation of the two major categories of waste oil, automotive and industrial, from region to region are noted. Per capita consumption is used as an indicator of this distribution. It is based on a population of approximately 200 million people in 1972, and a consumption of about 11 gallons of all lubricants per person per year.

A. NEW AUTOMOTIVE OILS
B. TOTAL EQUIVALENT NEW GREASE VOLUME (AUTO, AVIATION PLUS INDUSTRIAL)
C. TOTAL NEW INDUSTRIAL PLUS AVIATION LUBE OILS
D. TOTAL NEW OIL AND GREASE VOLUMES

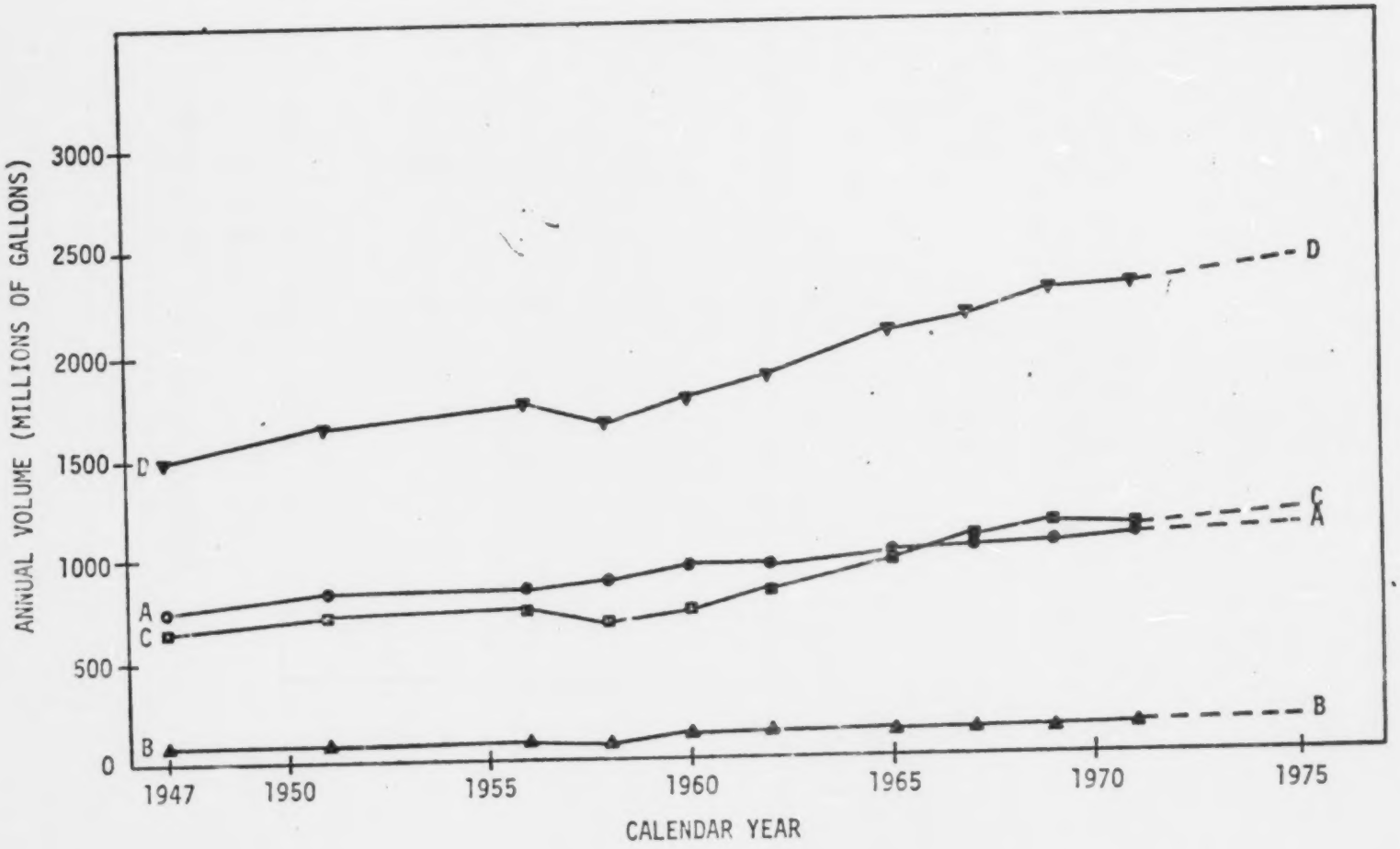
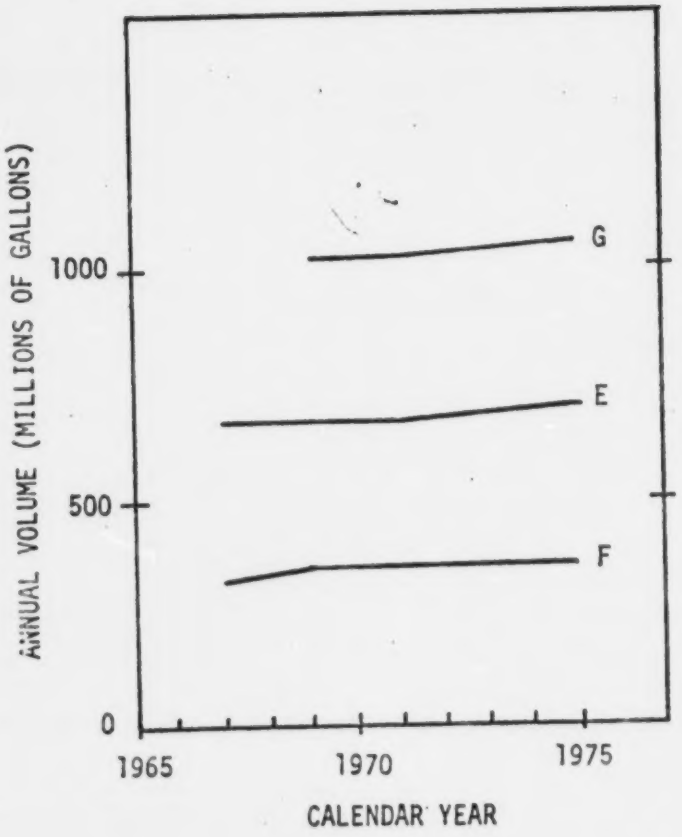


FIGURE 1, VIRGIN OIL SALES IN THE UNITED STATES

REFERENCE (5)



E. ESTIMATED WASTE CRANKCASE OILS
F. ESTIMATED WASTE INDUSTRIAL PLUS AVIATION LUBE OIL
G. ESTIMATED TOTAL WASTE OILS OF ALL CATEGORIES

FIGURE 2. WASTE OILS GENERATED IN THE UNITED STATES

REFERENCE (5)

Of this amount, approximately five gallons is assigned to the automotive oil category.

The exact causes for the variations in per capita oil consumption are not known but appear to be linked to regional characteristics such as degree of urbanization, level of agricultural activity and industrial output, coupled with the degree of development of public transportation. The regions or states having the highest proportion of per capita automotive oil consumption should generate a greater fraction of waste crankcase oil as compared with regions having higher per capita industrial oil consumption. Such consumption factors will affect the type of waste oils available for re-refining or other means of disposal. These variations are significant inasmuch as they affect the design of both the collection system and reprocessing system. Because of the greater spectrum of virgin oil products used industrially as compared with automotive uses, those regions having proportionately more industrial consumption will have more broadly varying waste oil types. In contrast, waste crankcase oils are found to be more uniform.

TABLE 3

ANNUAL PER CAPITA OIL USE IN UNITED STATES (1971)
(REF. 5)

STATE	OIL CONSUMPTION(GAL/PERSON/YEAR) Automotive	Industrial
Alabama	5.65	4.88
Alaska	7.05	2.15
Arizona	5.44	2.44
Arkansas	6.31	5.42
California	5.47	3.39
Colorado	5.65	2.94
Connecticut	3.37	4.07
Delaware	5.52	3.30
District of Columbia	3.25	Unknown
Florida	4.42	3.45
Georgia	5.57	5.52
Hawaii	3.66	Unknown
Idaho	7.30	1.86
Illinois	5.08	8.02
Indiana	5.17	8.45
Iowa	6.1	2.94
Kansas	10.0	4.62
Kentucky	7.02	7.10
Louisiana	6.31	11.20
Maine	5.10	2.8
Maryland	3.56	3.38
Massachusetts	3.57	3.64
Michigan	6.40	7.45
Minnesota	6.45	3.18
Mississippi	6.39	4.20
Missouri	6.91	3.35
Montana	9.15	2.45
Nebraska	9.50	3.91
Nevada	7.38	1.78
New Hampshire	3.45	1.18
New Jersey	3.82	8.70
New Mexico	7.10	5.15
New York	2.66	2.88
North Carolina	4.60	3.40
North Dakota	9.70	1.45

Table 3 continued

STATE	OIL CONSUMPTION(GAL/PERSON/YEAR) Automotive	Industrial
Ohio	5.21	9.45
Oklahoma	7.28	5.61
Oregon	8.71	4.81
Pennsylvania	4.59	7.97
Rhode Island	3.06	2.75
South Carolina	4.09	2.38
South Dakota	9.79	1.01
Tennessee	5.38	4.79
Texas	6.39	9.89
Utah	6.65	3.39
Vermont	4.54	1.45
Virginia	4.14	2.57
Washington	4.91	2.82
West Virginia	5.32	13.50
Wisconsin	5.92	3.88
Wyoming	11.70	4.79

B Physical and Chemical Characteristics of Waste Oils

The various sources described in the previous section may be classified into five broad types. These are: waste automotive lubricants, waste metalworking lubricants, waste heavy hydrocarbons (fuels and tars), waste animal and vegetable oils and fats, and waste industrial oil materials.

Waste Automotive Lubricants

Waste automotive lubricants includes all crankcase oils, transmission fluids, differential gear lubricants, hydraulic oils, and small quantities of solvents frequently used in automotive installations.

To a greater or lesser extent, automotive oils contain additives to improve their properties. These are synthetic organic chemicals and contain sulfur, nitrogen, oxygen and metals. Typical high grade automotive lubricating oil formulations contain 75 percent oil and 25 percent proprietary, or additive compounds.

Because of the blow-by in automotive engines, waste crankcase oils frequently have an appreciable portion of low boiling materials originating from gasoline. In addition, many of the constituents and additives in gasoline are transferred during engine operation to the crankcase. For example, lead is frequently found in concentrations of several thousand parts per million (ppm) in waste crankcase oil. Water is also found because of accidental introduction into waste holding tanks and because of moisture formed during combustion in the automotive engine. Frequently, appreciable solid material and sediment accompany the waste oils.

The contaminants in the waste automotive oil can be classified as volatile products, materials soluble in oil, and materials insoluble in oil. The volatile components generally are water and fuel. The soluble materials include many of the additives originally placed in the oil such as viscosity index improvers and detergent additives. The insoluble materials include sub-micron size carbon particles and inorganic materials such as atmospheric dust, metal particles, metal oxides and lead oxides originating during fuel combustion (4).

A typical analysis of waste oil is shown in Table 4 (5). In addition to the metals noted here, there are a large number of other trace metals present in used lubricating oils. A typical analysis of used lube oils showing the trace metal concentrations is given in Table 5 (6). It is evident from the entries in the trace metal table that appreciable amounts of lead, barium, calcium and zinc are found in most used motor oils. The exact amount reported on a given sample depends to some extent on the analytical method used as is evident from the differences between values determined by emission spectroscopy and atomic absorption. Individual samples, and perhaps many types of waste oil, vary widely in metal content. Lead concentrations may vary by an order of magnitude according to these data. This has important implications for waste oil processing.

Additional properties of these samples are shown in Table 6. These values are important in assessing the degree of contamination of the used lubricant and in determining methods of processing to convert used oils into useful products. Used automotive lubrication oils also contain appreciable amounts of gasoline introduced by means of blow-by as evidenced by the gasoline dilution test. They also contain relatively large amounts of sediment and water, and large amounts of ash. Much of the ash is due to additives originally blended with the oil. However, a large fraction of the ash originates from the fuel which contains lead and enters the oil by means of blow-by. These materials generally impair the use of spent lubricant either for further use as a lubricant or other applications until they are removed. Table 5 illustrates the large amount of metallic materials present in used crankcase oils. Although most compounded motor oils for modern internal combustion engines contain additives of organo-metallic nature, a large proportion of these compounds are introduced during use. Typically, the metals introduced by means of wear or combustion and corrosion are aluminum, copper, iron, lead, silicon and tin as tabulated in Table 5. Sodium, barium, calcium, zinc and magnesium frequently are added as compounds by the oil manufacturer to impart specific properties to the oil. As will be discussed in greater detail in other sections of this report, these metallic residues affect the ultimate treatment, use and disposition of waste crankcase oils.

Table 6 further describes the properties of used crankcase oils and illustrates the wide variations that may occur in the composition of used crankcase oils. For example, the gasoline dilution ranges from 0.8 percent to 7.2 percent. These values directly affect the fraction of re-refined oil that can be obtained from the used oil. Similarly, bottom sediment and water content (BS&W) affects subsequent reprocessing yields and methods.

It is interesting to note that the impurities found in used automotive lubricants are similar the world over. For example, Schilling reports French waste oils (3) to have a viscosity of 37 to 45 centistokes, bottom water and sediment of 2 to 8 percent, a water content ranging from 1 to 9 percent, and a gasoline dilution of up to 10 percent. Additional characteristics of used automotive lubricant oils have also been reported (7, 8). It is apparent that wide variations in composition may occur thus affecting the value of the waste oil for subsequent applications and affecting the ability to reprocess these materials.

One additional factor may come into consideration which will affect the chemical composition of waste oils. As the consumption of unleaded gasoline increases, the quantity of lead in waste crankcase oil will decrease. Since the removal of lead is a major problem in waste oil re-refining, this decrease in lead concentration may make the re-refining process more economically feasible.

TABLE 4

TYPICAL WASTE AUTOMOTIVE OIL COMPOSITION

(REF. 5)

Variable	Value
Gravity, °API	24.6
Viscosity @ 100 °F	53.3 Centistokes
Viscosity @ 210 °F	9.18 Centistokes
Flash Point	215 °F (C.O.C. Flash)
Water, (By Distillation)	4.4 Volume %
BS & W	0.6 Volume %
Sulfur	0.34 Weight %
Ash, Sulfated	1.81 Weight %
Lead	1.11 Weight %
Calcium	0.17 Weight %
Zinc	0.08 Weight %
Phosphorous	0.09 Weight %
Barium	568 ppm*
Iron	356 ppm*
Vanadium	5 ppm*

* ppm = parts per million

TABLE 5

USED AUTOMOTIVE LUBRICATING OILS

TRACE METALS CONTENTS

(REF 6)

Metal	Parts Per Million	
	Average	Range
Aluminum	16	10 - 30
Copper	28	5 - 120
Iron	361	150 - 800
Lead	1524	960 - 2070
Silicon	46	10 - 240
Tin	30	30
Sodium	64	20 - 110
Barium	269	10 - 900
Calcium	1772	1160 - 2690
Zinc	1111	560 - 1610
Magnesium	155	10 - 420

TABLE 6

USED AUTOMOTIVE LUBRICATING OILS

SELECTED PROPERTIES

(REF. 6)

Property	Average	Range
Specific Gravity	0.917	0.896 - 0.965
Viscosity @ 100° F SUS	436.000	262 - 753
Carbon Res. Conradson	6.5	3.8 - 12.6
Ash, %	2.49	1.57 - 3.78
Bomb Sulfur, Wt. %	0.44	0.26 - 0.52
Neutralization No.	6.67	4.00 -14.26
Benzene Insolubles, %	2.0	1.17 - 3.33
BS&W, %	6.3	3.2 - 9.3

TABLE 7

OIL-BASED METAL WORKING LUBRICANTS

(REF. 9)

CLASS I. OILS AND OIL BASE FLUIDS

A. Mineral Oils - Uncompounded

B. Fatty Oils

1. Uncompounded
2. Fatty Oils containing Chlorinated Compounds
3. Fatty Oils containing Sulfurized Compounds
4. Fatty Oils made by combining B-2 and B-3

C. Mineral Oils - Compounded

1. Mineral Oil/Fatty Oil Blends
2. Sulfurized and/or Chlorinated Mineral Oil
3. Mineral Oils containing Sulfurized Fatty Compounds and/or Sulfurized Non-Fatty Compounds
4. Mineral Oils containing Chlorinated Fatty Compounds and/or Chlorinated Non-Fatty Compounds
5. Mineral Oils containing Sulfo-Chlorinated Fats or Sulfo-Chlorinated Non-Fatty Compounds
6. Mineral Oils made by combining C-3 and C-4
7. Mineral Oils and/or Fatty Oils containing Nitrogen or Phosphorus Compounds or Solid Lubricants, etc. in addition to Compounds from the groups employed in C-1 through C-6

CLASS II. AQUEOUS EMULSIONS AND DISPERSIONS

A. Oil in Water Emulsions (Soluble Oils)

1. Mineral Oil - Emulsions of Class I-A
2. Mineral Oil/Fatty Oil - Emulsions of Class I-B(1) or I-C(1)
3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) through I-C(7)

B. Water in Oil Emulsions

1. Mineral Oil - Emulsions of Class I-A
2. Mineral Oil/Fatty Oil - Emulsions of Class I-B(1) or I-C(1)
3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) through I-C(7)

C. Colloidal Emulsions

1. Regular - Emulsions of Class I-A
2. Fatty - Emulsions of Class I-B(1) and I-C(1)
3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) through I-C(7)

D. Dispersions

1. Physical Dispersions of Liquid (Class I) Materials

Waste Metalworking Lubricants

Waste metalworking lubricants originate from the manufacture of various machinery articles. These include oil-based fluids used without water, and emulsified aqueous fluids consisting of physical mixtures of oil and water plus certain additives. Metalworking lubricants may be classified (9) into two broad classifications. These are shown in Table 7.

Under use, these coolants and lubricants are subject to deterioration and degradation caused by bacteria, heat, metal particles, oxidation, introduction of contaminants from water used to make the so-called soluble coolants, and the introduction of tramp oil and grease. In many cases, the metalworking fluids are recirculated, settled, filtered and subjected to other forms of purification enabling their reuse in the plant. Nevertheless, large quantities of these fluids must be disposed of. Both primary metal industries performing rolling and shaping of ferrous and non-ferrous metals, and hardgood manufacturers such as automotive and appliance manufacturers, generate significant quantities of waste oils. These oils when disposed of, are heavily contaminated with oxidized lubricant materials, sediment, and finely divided hard-to-filter particles. In general, used metalworking lubricants must be handled separately from other waste oils primarily because of their composition.

Waste Plant and Animal Oils and Fats

Waste plant and animal oils and fats originating from the food processing and edible oil manufacture generally are recovered as soap stocks, animal feed additives and similar uses. However, a small amount of these oils and fats fall into the category of oily waste materials and are not suitable for further processing. Typically, these waste materials consist of fatty acids and glycerol esters of saturated and unsaturated fatty acids. Frequently the melting point of these materials is above room temperature and they may be discarded along with other "solid" wastes. Oily wastes from margarine manufacture and cooking operations have been reported to range from 60 to 80 percent oils and fats; the balance consisting of water, dirt, salt, milk solids, and other contaminants. The heating value of the oily fraction of this mixture is approximately 17,000 BTU per pound (10).

Other Oils

The physical and chemical characteristics of a variety of other industrial wastes depend on the specific application and composition of the original lubricant or oil. Typically, these wastes consist of spent turbine oil, spent transformer oil, mixtures of aviation jet fuel and lubricants, gear box oils from industrial rotary machinery, heat transfer fluids, railroad lubricants, and coke oven oils.

A small amount of fireproof transformer oils such as commercial mixtures of tri-chlorobenzene and polychlorinated biphenyls enter into the waste category each year (11). Because of the persistent nature and non-biodegradability of these materials, they are not normally discharged into the environment. Instead they are disposed of by controlled incineration in approved facilities.

Used gear oils usually are mixed with other plant oily wastes for ultimate disposal. These gear oils have SAE numbers ranging from 80 up to 250. They frequently contain sulfur-bearing or lead-bearing additives, antioxidants, and other additives. After use, these lubricants become contaminated with dirt, wear metal, water, and products of oxidation. These waste lubricating materials have properties similar to automotive crankcase lubricants and may be included with them for re-refining or other means of disposal (12).

The manufacture of coke for metallurgical and other purposes usually is attended by a formation of waste oils. These may be accumulated from tar and grease separators and by lagooning. These oils are combustible and may be used either as fuels or incinerated.

Oily Wastes from Refining Operations

Oily wastes from petroleum refining operations can originate in various steps of the refining process. The total quantity of these waste materials usually recovered in API separators in a refinery may range from 0.1 to 2 percent of the total crude oil throughput (13). However, a value of somewhat less than 1/2 percent appears to be more frequent.

Because of the large number of products produced in the petrochemical industry, the composition of recoverable slop oils from petroleum processing operations varies widely (14). Generally these recovered slop oils may be reused in some of the processing operations, used as fuels, or incinerated (15).

Waste Oily Materials from Re-Refining

Waste oily materials from re-refining of spent automotive and industrial lubricants contain many impurities. Typically these materials are the result of acid and clay treatment procedures, distillation and filtration operations. The waste oily sludges resulting from these operations have been reported (16) to have an API gravity of 1 to 2 degrees, a lead concentration of 1.9 percent, barium ranging from 500 to 1,000 ppm, zinc around 2,000 ppm, a pH range of 4 to 8, approximately 50 percent water, and up to 20 percent dirt. The results of a typical analysis are shown in Table 8 which lists the metal content of the waste oily sludge remaining after re-refining of predominantly used crankcase oils. The high concentration of metal in this waste oil sludge indicates that this material must be treated further prior to ultimate disposal.

TABLE 8

METAL CONTENT OF WASTE OIL RE-REFINING OIL SLUDGE

(REF. 16)

Element	Concentration (ppm)
Zinc	2100
Cadmium	9
Arsenic	45
Boron	18
Phosphorous	1700
Iron	2200
Molybdenum	18
Manganese	63
Aluminum	560
Beryllium	0.1
Copper	190
Silver	0.8
Nickel	8
Cobalt	0.8
Lead	19,000
Chromium	28
Vanadium	18
Barium	740
Strontium	2.7

C. Present Methods of Collection and Disposal

1. Methods of Collection

Waste oil collection methods vary greatly, especially those involving the collection of automotive oils from service stations. In some areas of the country, waste oil scavengers remove the materials from the service station and transport it to a re-refining facility or elsewhere for other uses of the material. In other areas, no such service exists and the final disposition of the oil cannot be readily identified. In the case of industrial users, their waste oil is usually sent to a custom re-refiner and reprocessed before it is returned to the original user.

2. Disposal and Recovery of Waste Oils

This report discusses the viable options available today for the disposal and/or recovery of waste oil. These include re-refining, use as fuel oil and use in land applications. Other illegal or unacceptable methods of disposal are noted.

a. Re-Refining

Petroleum re-refining is a small industry generally using old process technology and antiquated equipment. With few exceptions re-refiners can be considered marginal operations. While no definitive statistics are available, it appears that the number of processors as well as capacity is decreasing. Based on limited discussions, the economic squeeze is partly due to size and inefficient equipment and partly due to the increase in additives and the changes in the tax structure on recycled oil.

A sample of 29 re-refiners indicates that the typical processor has a 28,000 gal/day capacity and operates at 50 percent of that capacity. Capacities vary between 2,200 and 130,000 gal/day. Reported plant sizes and limitations are summarized in Table 9.

Feed is obtained from a variety of sources. Many re-refiners will not accept crankcase oil, sand bottoms or bilge water. That is, they will only handle relatively uncontaminated feeds. This is an easier, cheaper process sequence with fewer waste disposal problems and results in cleaner product. Special custom job re-refiners usually cater to a particular industry. They take the waste, process it, and return it to the owner. Typically, transformer oils, railroad and some industrial lubricants can be handled in this manner. About 50 percent of the re-refiners to custom re-refining since this is the most attractive business.

TABLE 9 - DATA SURVEY OF SELECTED OIL RE-REFINERS (1)

COMPANY[1]	PROCESS[2] A	B	C	Other	CAPACITY (gpd) Design	Operating	SOURCES OF FEED[3,*] D	E	F	G	H	I	J	PRODUCTS[4,**] K	L	M	N
No. 1	X	X	X	--	--	5,000	4,000	X	-	-	X	-	X	XX	X	-	X
No. 2	X	X	X	--	2,200	2,100	2,000	X	X	X	X	-	-	XX	-	-	-
No. 3	X	X	X	--	23,000	13,000	12,000	X	X	X	X	-	-	XX	X	-	-
No. 4	X	X	X	Batch Basis	--	9,000	--	--	X	-	X	-	-	X	-	-	X
No. 5	-	-	-	--	--	--	--	--	-	-	-	-	-	-	-	-	
No. 6	X	X	X	3/4 Capacity	20,000	20,000	16,700	--	X	X	6,200	-	-	XX	X	-	X
	X	days	X	1/4 Capacity													
No. 7	-	-	-	HiPres. Dist.	130,000	65,000	XX	X	X	X	X	X	X	-	XX	X	-
No. 8	X	X	X	--	62,500	50,000	X	XX	-	-	X	-	-	X	-	-	X
No. 9	X	X	X	w/Steam Strip	4,300	3,200	2,750	X	-	-	X	-	-	XX	-	-	X
No. 10	X	X	X	--	6,500	3,250	3,000	--	-	-	-	-	X	XX	-	-	-
No. 11	-	-	-	Dry,HiSpdCent	12,500	12,500	11,200	--	X	-	X	-	X	XX	X	-	X
No. 12	X	X	X		5,250	5,250	4,700	--	X	X	X	-	-	XX	-	-	X
No. 13	-	-	X	Caustic Clay	17,000	17,000	XX	--	-	-	X	-	X	XX	-	-	X
No. 14	X	X	X	--	20,000	10,000	XX	X	-	-	X	-	X	XX	-	-	-
No. 15	X	X	X	Steam Strip	--	8,300	4,100	X	-	-	XX	-	-	XX	-	-	-
No. 16	X	X	X	--	12,500	10,500	5,000	X	-	-	X	-	-	XX	X	-	X
No. 17	X	X	X	--	--	20,000	12,000	-	-	-	X	-	-	XX	-	-	X
No. 18	X	X	X	Steam Strip	12,500	12,500	XX	X	-	-	X	-	-	XX	X	-	X
No. 19	X	X	X	--	7,500	7,500	XX	-	-	-	-	-	-	XX	-	-	-
No. 20	X	X	X	--	8,300	8,300	6,250	-	-	-	X	-	-	X	-	-	X
No. 21	-	-	X	Caustic Clay	40,000	30,000	XX	X	-	-	X	X	-	XX	-	X	-
No. 22	X	X	X	--	33,000	20,000	XX	X	-	X	X	-	-	XX	-	-	X
No. 23	X	X	X	--	17,000	10,000	7,000	X	-	-	X	-	X	X	X	XX	X
No. 24	-	-	X	Caustic Clay HCl Act. Clay	25,000	5,000	4,500	X	-	-	X	-	-	XX	-	-	X
No. 25	-	X	X	--	6,700	2,000	2,000	-	-	-	-	-	-	XX	-	-	-
No. 26	X	X	X	--	--	1,000	1,000	-	-	-	-	-	-	XX	-	-	X
No. 27	X	X	X	--	3,600	2,000	2,000	-	-	-	X	-	-	XX	-	-	X
No. 28	X	-	X	--	40,000	20,000	X	X	-	-	X	X	X	XX	-	-	-
No. 29	-	-	-	--	33,000	--	X	X	-	-	X	-	X	-	X	-	X
TOTAL					636,850	372,400											
AVERAGE					28,000	14,000											

1,2,3,4,*,** - See Legend

2-Process
- A - Dehydration
- B - Acid - Clay
- C - Distillation

3-Sources of Feed
- D - Automotive Crankcase
- E - Commercial Crankcase (Truck fleets, Railroad, Aircraft, etc.)
- F - Hydraulic Fluids
- G - Transformer Oils
- H - Industrial Lubes
- I - Tank Bottoms
- J - Other Sources

4-Products
- K - Motor Lubricants
- L - Heating Oil
- M - Diesel Oil
- N - Other Products

* x - Minor Waste Oil Source
xx- Major Waste Oil Source

** x - Minor Re-Refining Product
xx- Major Re-Refining Product

(1) EPA EWORL Study of 3/73

Most of the waste oil presently reprocessed is sold as motor or industrial lubes. The motor oil is usually sold through discount or food chains while industrial lubes are sold in bulk. According to preliminary studies conducted by the Bureau of Mines, this oil is not compounded (no additives added) and lacks lubricating power (17).

Waste oil refining, with few exceptions, employs acid-clay treating. A typical flow scheme may be found in Figure 3. Generally, although not necessarily, water is removed from the oil in a dehydrator. If dehydration is omitted, acid requirements increase. Clay without acid is used in some cases, but requires eight times as much clay as the acid-clay treatment. Contacting with sulfuric acid follows to remove some of the impurities in an acid sludge which presents the first critical disposal problem. Contacting with an activated clay at 400-550°F follows to remove the remaining metal and other inpurities. The spent clay is separated from the oil in a filtration step. The filter solid (spent clay) contains 30-50 percent oil, metal contaminants and other impurities such as carbon. This material is generally disposed of in a sanitary landfill; a practice which is environmentally unacceptable. Alternate process sequences are being sought because of the disposal problems as well as high cost and low yields. The high additives content of current, high detergent, motor oils also present a problem as these additives and some of their degradation products are not removed.

Several re-refiners use distillation with minimal chemical treatment. Typically straight distillation yields a fuel oil from relatively clean feed stocks; i.e., those containing water, some degradation products, carbon but essentially no metals. Only limited straight vacuum distillation on waste crankcase oils has been carried out without chemical pre-treatment since fouling is a difficult operating problem. Moreover, disposal of the bottoms with their high metals content has in the past also mitigated against use of this approach.

At least one re-refiner substitutes caustic for acid treatment. This process was studied under an FWPCA grant (7). This treatment is followed by vacuum distillation. The operating problems are not significantly different nor are the sludge disposal problems solved. This sludge may be sold as a commercial detergent base. The product yield claimed is higher than with acid treatment. This is not conclusive, however, as feed stock will significantly affect yield. In preliminary laboratory experiments the higher yields (80 to 90 percent) were confirmed but required special vacuum fractionation to obtain good yields (17). New approaches are currently under development. Of these new approaches, solvent extraction and hydrotreating in combination with distillation appear most promising.

The Institute Francis du Petrole (IFP) is operating a 9 million gal per year plant incorporating a propane solvent extraction followed by

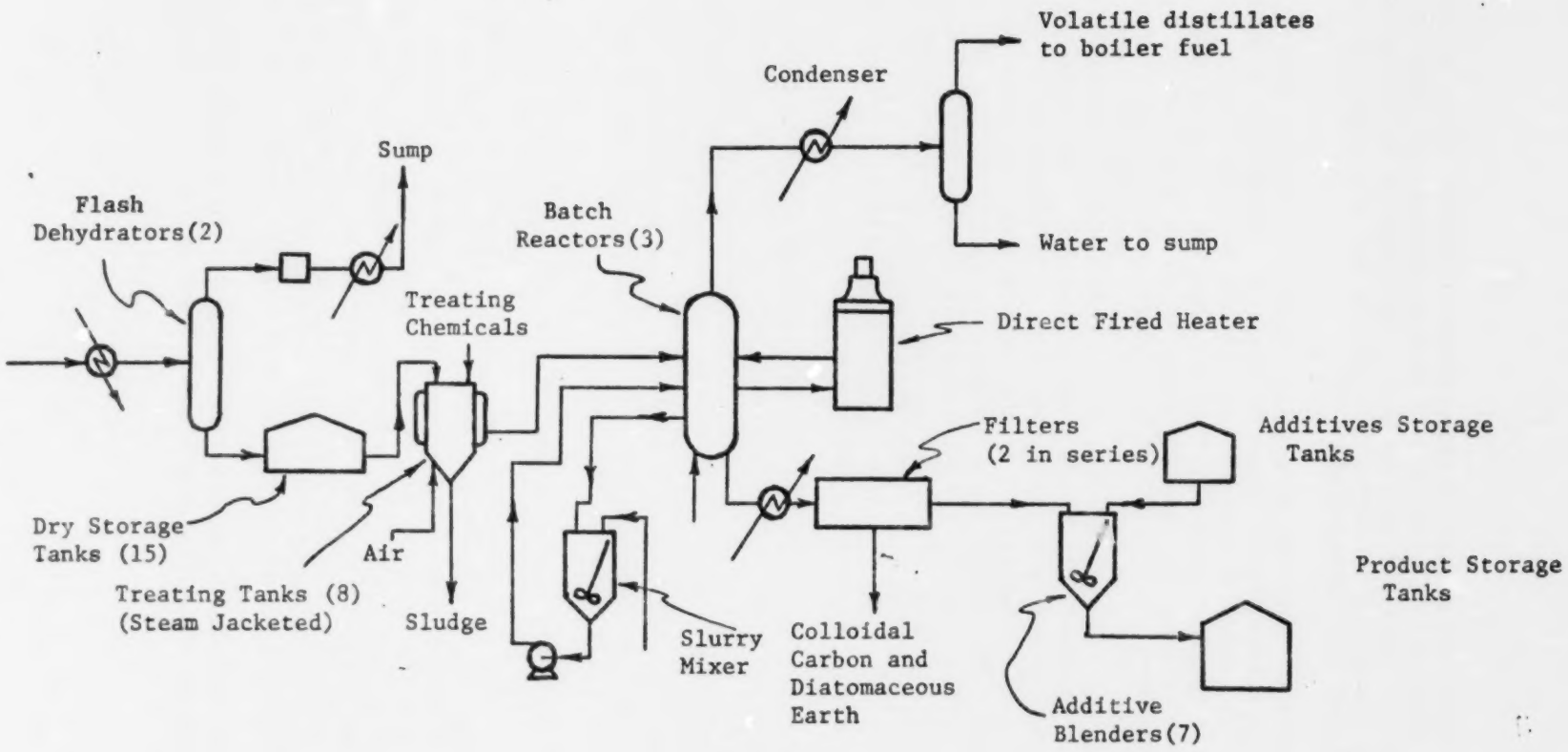


Figure 3 - Flow Scheme For Acid-Clay Type Re-Refining Process

a light acid clay treatment. A conceptual flow plan of the process is shown in Figure 4. IFP claims that the process:

- Reduces acid and clay consumption 80 percent
- Reduces acid sludge by 80 percent
- Increases product yield 10 percent
- Produces a higher quality oil.

The process is patented but insufficient data have been published to fully evaluate the economics. In Europe the process appears attractive as IFP is reportedly planning to construct a second plant (18).

EPA is sponsoring work with the National Oil Recovery Corporation (NORCO) to develop and demonstrate a process to recover waste crankcase and other oils. The process as conceptualized will not yield any by-products, such as spent clay, which present disposal problems. Three approaches are being studied:

- Straight Vacuum Distillation (Figure 5)
- Solvent Extraction Followed by Distillation (Figure 6)
- Distillation and Hydrotreating (Figure 7)

Distillation has been demonstrated and can, under proper operating conditions and in a properly designed unit, produce products which meet specifications for fuel, lube, or diesel oil. Color stability of the product and gum formation continues to be a problem. A light hydrotreatment will solve the problem. Limited laboratory runs have produced a product which has been color stable for 9 months. Some work soon to be published has been carried out by Esso in this area and confirms that hydrotreating can be used successfully if metals content is low (19). Further hydrotreating pilot plant studies to check catalyst life and operating conditions are planned for later this year.

The distillation bottoms product containing 25 percent solids includes essentially all the metals and must be further concentrated to improve oil yields and disposability. Physical methods of concentration, such as filtration and centrifugation, do not appear to be applicable based on preliminary laboratory evaluation. Solvent extraction does hold promise. This may be carried out on the feed or bottoms, with each having process and economic advantages and disadvantages. An essentially oil and solvent free solid product is obtained. This solid has about a 10 percent lead content, higher than any available lead ore. Samples of both dry solid and oily bottoms have been evaluated by a metal refiner for their potential value. Preliminary results of the evaluation are favorable; the dry solid form being the most desirable. Additional work is required with larger quantities for pilot plant scale testing to confirm these findings.

To date only limited glassware studies have been carried out on solvent extraction. These include some early work at Armour Research Foundation and current work underway at NORCO. Others have also carried out.

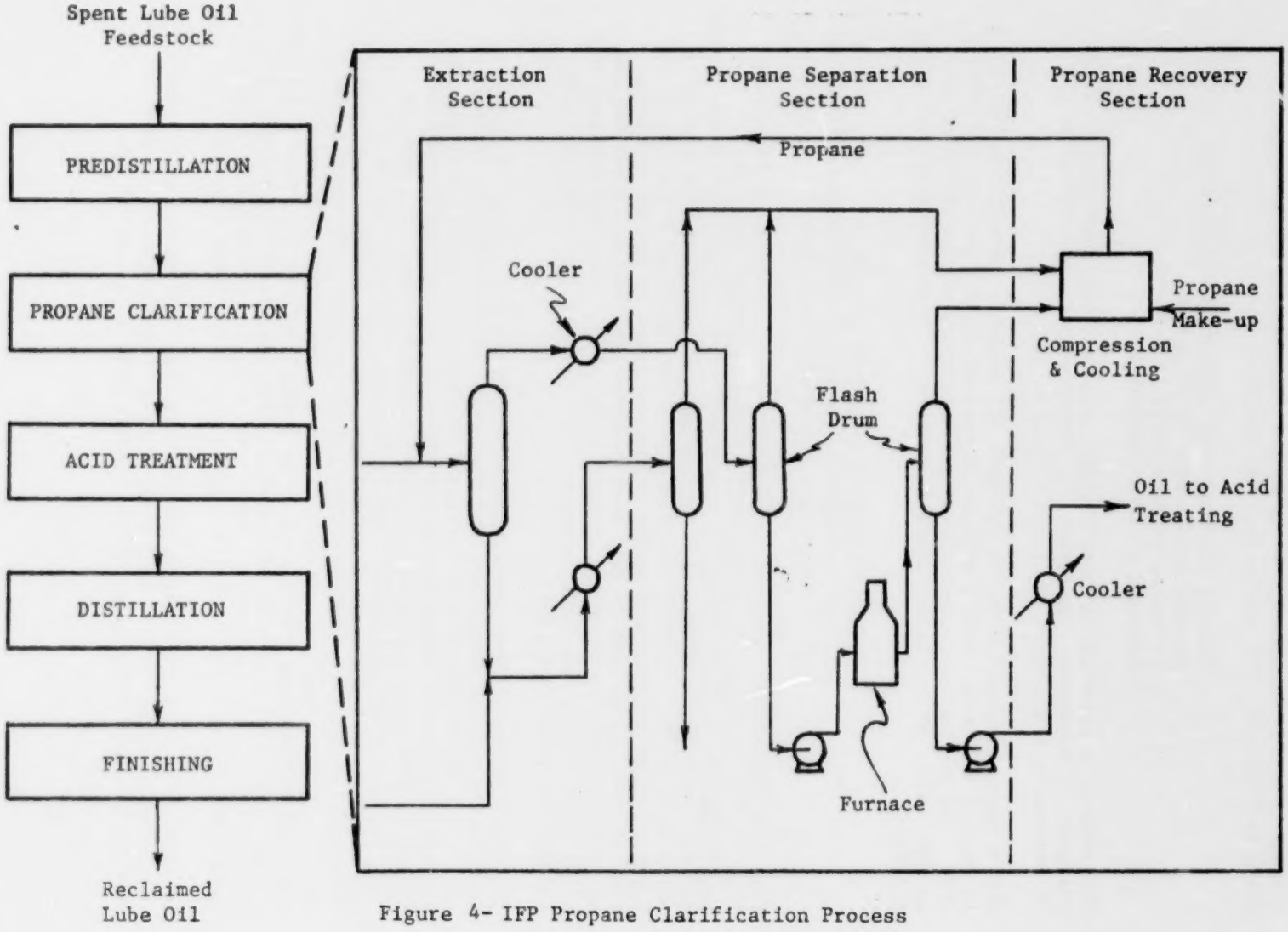


Figure 4- IFP Propane Clarification Process

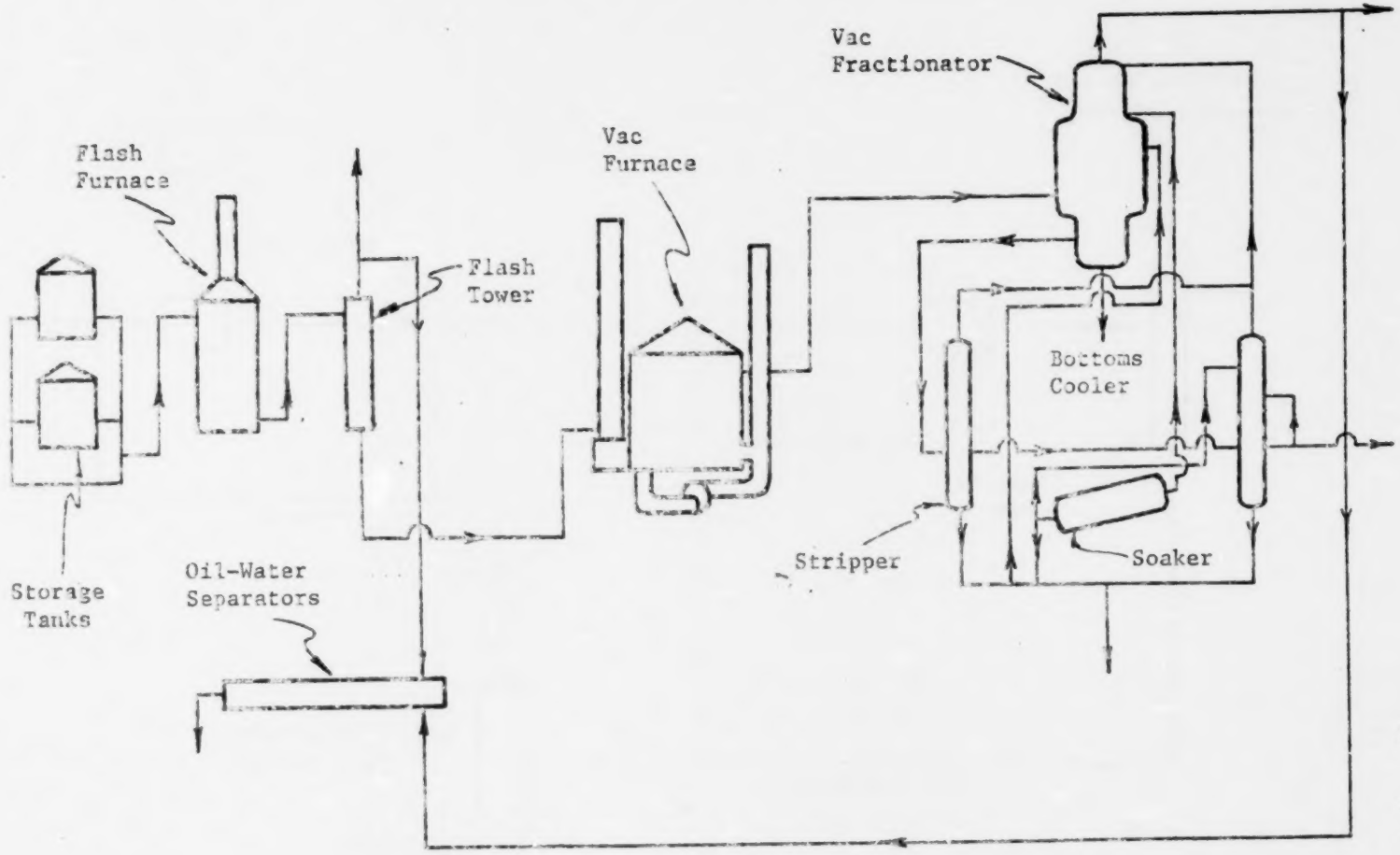


Figure 5 - National Oil Recovery Corporation Project Flow Sheet

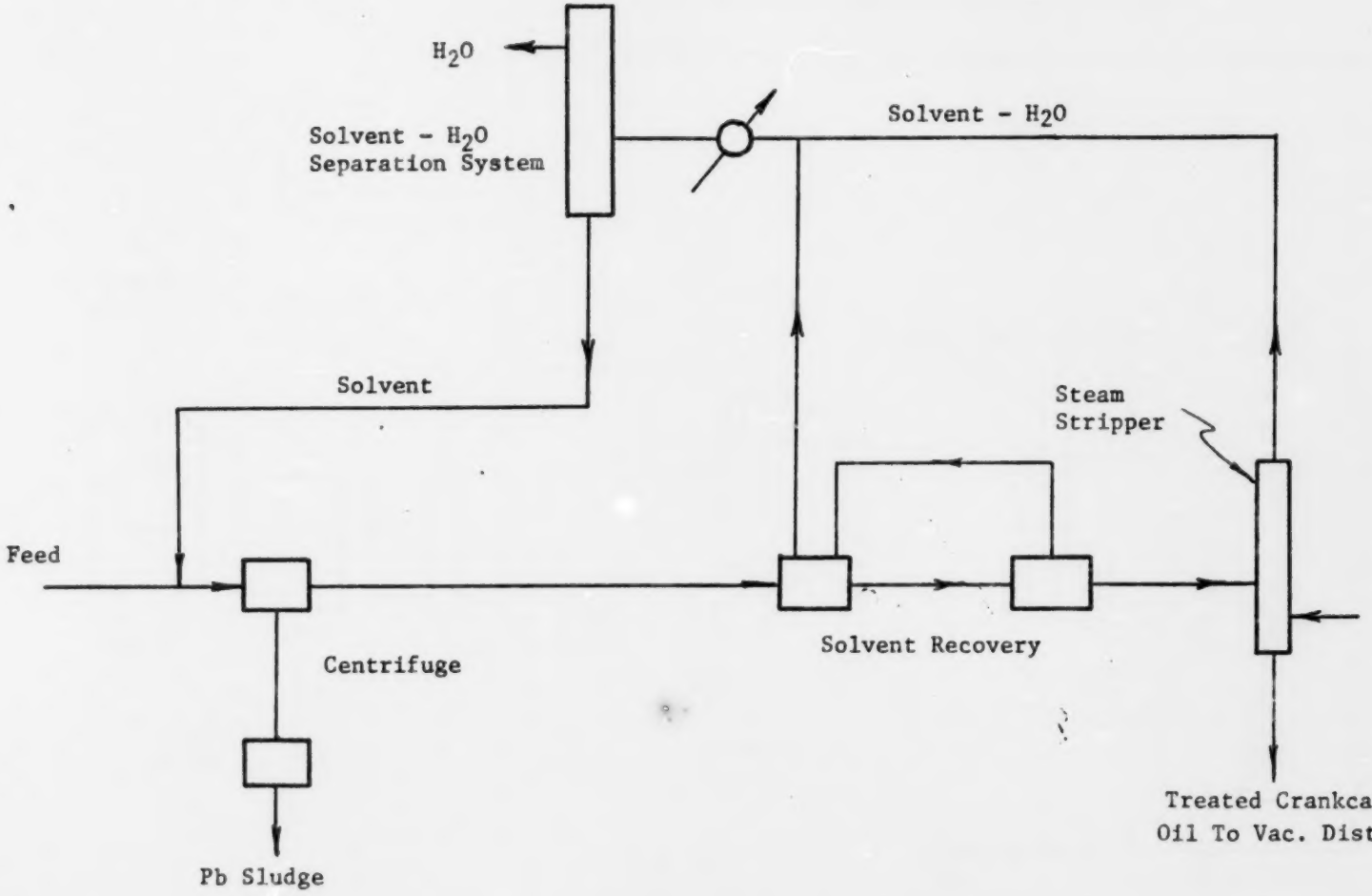


Figure 6 - Solvent Extraction - Waste Oil Treatment

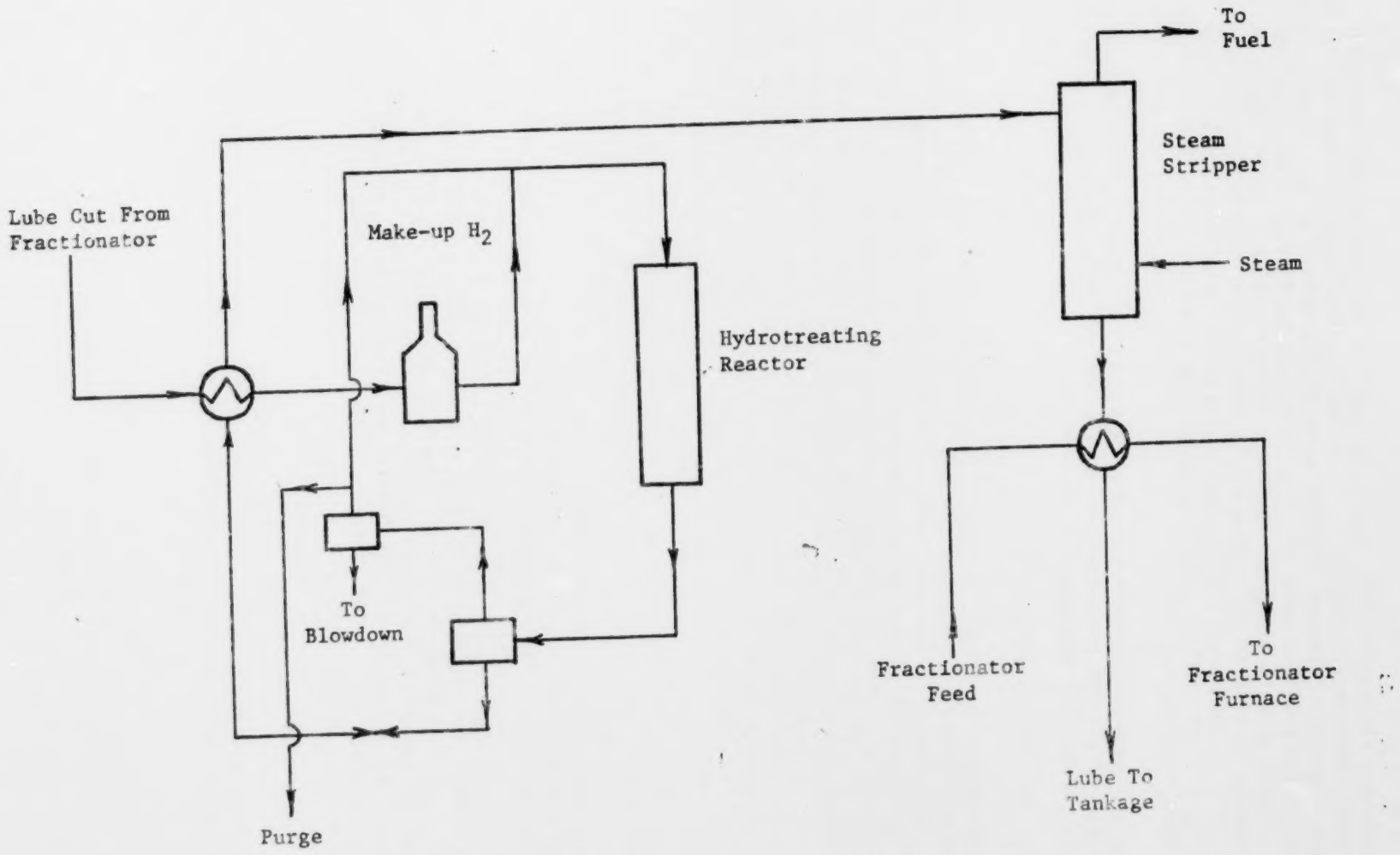


Figure 7 - Waste Oil Hydrotreating - Distillation Process

preliminary studies in this area. No one, to the best of our knowledge, has considered metals recovery. As a result, the economics when compared to the acid-clay treatment process were always unfavorable. In most cases, solvent to oil ratios were too high to obtain sufficient sludge removal. The current work is aimed at finding a suitable solvent system which, with reasonable solvent to oil ratios, will provide essentially total metals separation. Once a suitable solvent system has been found, pilot scale testing will proceed to establish operating criteria. This work is scheduled for completion during 1974.

There are numerous patents issued on waste oil treatment processes (20). Essentially all the processes are variations of those discussed above and are not being used commercially at present.

b. Use as a Fuel Oil

Another use of waste oil is its utilization as a fuel oil as the waste oil contains essentially the same BTU content per pound as does the virgin oil. The Environmental Protection Agency funded a study (21) to determine the feasibility of utilizing waste crankcase oil as a fuel for solid waste incinerators. These incinerators currently use heating oil as a fuel when burning wet refuse. Preliminary results of the study indicate that incineration equipment is available which can utilize waste crankcase oil as a fuel without clogging the burner heads and that the waste crankcase oil has a sufficient heat content for the process. However, before utilizing this technology on a full scale incinerator, it will be necessary to develop a method for the removal of the lead present in the waste oil. Preliminary testing indicated there is severe fouling of the boiler interior with inorganic ash. Moreover, about 50 percent of the inorganics in the waste oil were emitted in the flue gas as submicron range particles high in lead content (22). Additional work must be done to either demetallize the oil prior to burning or provide adequate effluent scrubbing systems. This can be done either by pretreatment of the oil prior to burning or by installing suitable stack gas scrubbing equipment. If this is not done, the lead entering the atmosphere may cause an air pollution problem.

Others are also studying the application of waste oil as a fuel. At the Aberdeen Proving Ground in Maryland, waste oil is being mixed with virgin fuel in ratios up to ten percent to determine the effect on combustion equipment. A group in Massachusetts is planning to utilize waste oil as a fuel in a steam generating plant on an experimental basis. This experiment will be monitored to determine if any increase in air pollutants is noted.

c. Use in Land Application

Waste oils are being used to oil roadways for dust control. Limited experimental work has been carried out at the EPA's Edison Research

Laboratory (22) to evaluate the environemntal significance of this disposal method. It appears that about 30 percent of the oil volatilizes and is biodegraded. Only 1 percent of the oil remains on the roadway after more than ten years. The remaining 70 percent of the oil apparently leaves the roadway either on dust particles or in water runoff. Thus, a major portion of the metal contaminants in the waste oil may also be expected to enter the ecosphere.

Another method of disposal is by burying in a sanitary landfill or otherwise spreading on land. If this method is employed, extreme care must be exercised to assure that ground water supplies are not contaminated by oil leaching through the soil.

d. Other Disposal Methods

It has previously been indicated that only about 10 percent of the waste crankcase oil produced is handled by re-refiners. Similarly, only a small portion is used as a fuel or as a road oil. The remainder of the waste crankcase oil is presently unaccounted for. Although we are unable to cite specific examples, it is known that a portion of this material is accidently or intentionally dumped either on land or in the water. These dumping incidents range from the automobile owner who has changed his engine oil and dumps the waste oil into a sewer or directly into a stream to the waste oil scavenger who picks up at service stations and then proceeds to dump his truckload of waste oil illegally.

D Biological Effects of Waste Oil (24, 25, 26)

1. Waste Oil in the Aquatic Environment

The biological effects of the introduction of waste oils into the freshwater and marine environments have received only a cursory scientific review. Comprehensive laboratory and field investigations of waste oils have not been conducted. A reasonable amount of quantitative data exists on the effects of crude oils on the flora and fauna of estuaries and inshore areas. The data reported are primarily for benthic organisms, rooted and attached aquatics, and waterfowl. Based on these data, the effects of waste oil on the biology of freshwater and marine organisms can only be addressed in the most general terms. In fact, it must be pointed out that, until sufficient data are generated specifically on waste oil effects, we will not know if we are even in the right ball park as to recommendations.

Public Law 92-500 Section 104(m)(1)(B) requires studies of long-term chronic biological effects of waste oils. It should be clearly recognized that valid quantitative long-term chronic data on effects of waste oil are not available; and within the time frame of the required preliminary report, no information on waste oil can be presented. Only limited quantitative information will be available for the final report. In light of the above, the Agency is forced to make recommendations regarding waste oil based on the availability of information on the effects of crude oil and limited numbers of refined oils. Furthermore, only precarious assessments can be made on the suspected metals contained in waste oils. The effects on aquatic life of heavy metals singly and in combination currently are being evaluated. Preliminary results in both acute and chronic tests show that effects of heavy metals on aquatic organisms are as variable as the chemistry of the aquatic environment; that is, additive synergistic and antagonistic effects are obscure for various metals combinations.

Although accidental oil spills are spectacular events and attract the most public attention, they constitute only about 10 percent of the total amount of oil entering the environment. The other 90 percent originates from the normal operation of oil-carrying tankers, other ships, offshore production, refinery operations, and the disposal of waste-oil materials.

Two other sources of oil contamination of the sea are the seepage of oil from natural hydrocarbon seeps and the transport of oil in the atmosphere from which it precipitates on the surface of the sea. The natural seepage source is probably small compared to man-made inputs to the ocean; but the atmospheric transport, which includes hydrocarbons that have evaporated or been emitted by engines after incomplete combustion, may be greater than the natural direct input.

Origins of Oil Pollution

Some of these sources of oil pollution can be controlled more rigorously than others, but without application of adequate controls wherever possible the amount of petroleum hydrocarbons entering the waters will increase. Existing technology is based upon an expanding use of petroleum. The production of oil from submarine reservoirs and the use of shipping to transport oil to meet this need will both increase. It is estimated that the world production of crude oil in 1969 was nearly 2 billion tons; on this basis total losses to the sea are somewhat over 0.1 percent of the world production. Some losses in the exploitation, transportation, and use of a natural resource are inevitable; but if this loss ratio cannot be radically improved, the oil pollution of the ocean will increase as utilization increases.

Principal sources of oil pollution are listed in order of their destructiveness to ecosystems; these sources are:

1. Sudden and uncontrolled discharge from oil and gas wells.

2. Spillage of oil during loading and unloading operations, leaky barges, and accidents during transport.

3. Discharge of oil-contaminated ballast and bilge water into coastal areas and on the high seas.

4. Cleaning and flushing of oil tanks at sea. On the average, a ship's content of such wastes is estimated to contain 2 to 3 percent oil in 1,000 to 2,000 tons of waste.

5. Spillage from various shore installations, refineries, railroads, city dumps, garages, and various industrial plants.

Losses of oil that can have an adverse effect on water quality and aquatic life can occur in many of the phases of oil production, refining, transportation, and use. Pollution may be in the form of floating oils, emulsified oils, solution of the water soluble fraction of these oils, or precipitated oils.

The problem of oil pollution has received considerably more attention in the marine environment than in the freshwater environment. However, the consequences of a large oil spill in a confined area such as a river or a lake could be far more serious than those of a spill in open waters. The threat of such a disaster is increasing because of the increased use of oil as a substitute for coal. The continuous or intermittent release of lesser quantities of petroleum products to inland waters as a result of refining, transportation, and use can be equally as important and merits special attention in freshwater ecosystems. Additional research is needed to determine:

1. Safe levels of sedimented oils.

2. The biological implications of the ability of sedimented oils to concentrate other toxic substances such as chlorinated hydrocarbons.

3. The effects of oil dispersents on aquatic life.

4. The variability in toxicity of different crude oils.

5. The effects of oil on other toxicants.

Toxic Effects of Oil

Oil is a mixture of many compounds, and there are conflicting views concerning its toxicity to marine organisms. Crude oils differ markedly in their chemical composition and in such physical properties as specific gravity, viscosity, and boiling-point distribution. The hydrocarbons in oil cover a wide range of molecular weights from 16 (methane) to over 20,000. Structurally, they include aliphatic compounds with straight and branched chains, olefins, and the aromatic ring compounds. Crude oils differ mainly in the relative concentrations of the individual members of these series of compounds. The various refinery processes to which oil is subjected are designed to isolate specific fractions of the broad spectrum of crude oil compounds. However, the refined products or fractions themselves remain complex mixtures of many types of hydrocarbons.

In spite of the many differences among them, crude oils and their refined products all contain compounds that are toxic to species of marine organisms. When released to the marine environment, these compounds react differently. Some are soluble in the water; others evaporate from the sea surface from extensive oil slicks; and some settle to the bottom if sand or detritus becomes incorporated in the oil globule. More complete understanding of toxicity and the ecological effects of oil spills will require studies of the effects of individual components, or at least of classes of components, of the complex mixture that made up the original oil. The development of gas chromatography has made it possible to isolate and identify various fractions of oil and to follow their entry into the marine system and their transfer from organism to organism.

When an oil spill occurs near shore or when an oil slick is brought to the intertidal zone and beaches, extensive mortality of marine organisms occurs. When the Tampico Maru ran aground off Baja, California, in 1957, about 60,000 barrels of spilled diesel fuel caused widespread death among lobsters, abalones, sea urchins, starfish, mussels, clams, and hosts of smaller forms.

The oil spills from the wreck of the tanker Torrey Canyon and the Santa Barbara oil well blowout both involved crude oil. In both cases,

oil reached the beaches in variable quantitites some time after release. The oil may thus have been diluted and modified by evaporation or sinking before it reached the beach. In the Santa Barbara spill, many birds died and entire plant and animal communities in the intertidal zone were killed by a layer of encrusting oil often 1 or 2 centimeters thick.

In September 1969 a relatively small oil spill in West Falmouth, Massachusetts, occurred within a few miles of the Woods Hole Oceanographic Institution. An oil barge, the Florida, was driven onto the Buzzards Bay Shore where it released between 650 and 700 tons of No. 2 fuel oil into the coastal waters. Studies of the biological and chemical effects of this spill still are continuing three years after the event. Massive destruction of a wide range of fish, shellfish, worms, crabs, other crustaceans, and invertebrates occurred in the region immediately after the accident. Bottom-living fish and lobsters were killed and washed ashore. Dredge samples taken in 10 feet of water soon after the spill showed that 95 percent of the animals collected were dead and the others moribund. Much of the evidence of this immediate toxicity disappeared within a few days either because of the breaking up of the soft parts of the organisms, burial in the sediments, or dispersal by water currents. Careful chemical and biological analyses reveal, however, that not only has the damaged area been slow to recover but the extent of the damage has been expanding with time. A year and half after the spill, identifiable fractions of the source oil were found in organisms that still survived on the perimeter of the area. Hydrocarbons ingested by marine organisms may pass through the wall of the gut and become part of the lipid pool. When dissolved within the fatty tissues of the organisms, even relatively unstable hydrocarbons are preserved. They are protected from bacterial attack and can be transferred from food organism to predators and possibly to man.

The catastrophic ecological effects of the oil spills of the Tampico Maru, and the Florida appear to be more severe than those reported from other oil spills such as the Torrey Canyon and the Santa Barbara blowout. The Tampico Maru and the Florida accidents both released refined oils (in one case diesel oil and in the other, No. 2 fuel oil) and both occurred closer to shore than either the Torrey Canyon or the Santa Barbara accidents which released crude oil. The difference in the character of the oil and the proximity to shore may account for the more dramatic effects of the first two accidents, but it is clear that any release of oil into the marine environment carries a threat of destruction and constitutes a danger to world fisheries.

The oil and sewage pollution effects on aquatic organisms of the Novorossiyak Bay (Black Sea, U.S.S.R.) were recently studied. For a number of years, this bay has been receiving a mixed daily discharge of 15,000 to 30,000 cubic meters of petroleum refinery wastes and domestic sewage. There is marked decrease of various valuable species of mollusks (Spisula substrumcata, Tapes rugates, Pecten ponticus) and complete destruction of oyster beds (Ostrea taurica) due to the combined effect of pollution by a carnivorous gastropod (Rapana). Samples were collected 1 to 25 meters from the outfall. Copepods

(Acartia clausi) placed in samples taken 25 meters from the outfall were killed in 24 hours. Larvae of decapods and gastropods in samples taken 10 to 25 meters out perished in 3 to 4 days. Calanus was killed in 5 days in samples taken 1 meter out, but survived the 10-day test in the samples taken 5, 10, and 25 meters from the outfall. There also was a noticeable change in the distribution and species composition of benthic algae.

It has been found that unburned fuel oil escaping through the funnels of oil-burning ships may comprise 1 to 2 percent of the total oil consumed and it may be deposited on the sea surface. British investigators attributed the disappearance of eel grass (Zostera) to minute quantities of oil. Oil weakens the plant and makes it susceptible to attacks of a parasitic protozoan (Labyrinthula). Observations made several years ago at Woods Hole showed that young Zostera that began to reappear in local bays after several years of absence were already infected by this micro-organism even though they appeared to be healthy.

As mentioned, oil can be ingested by marine organisms and incorporated into their lipid pool. Hydrocarbons in the sea are also degraded by marine microorganisms. Very little is known as yet about the rate of this degradation, but it is known that no single microbial species will degrade any whole crude oil. Bacteria are highly specific, and several species will probably be necessary to decompose the numerous types of hydrocarbons in a crude oil. In the process of decomposition, intermediate products will be formed and different species of bacteria and other micro-organisms may be required to attack these decomposition products.

The oxygen requirement of microbial oil decomposition is severe. The complete oxidation of one gallon of crude oil requires all the dissolved oxygen in 320,000 gallons of air-saturated sea water. It is clear that oxidation might be slow in an area where previous pollution has depleted the oxygen content. Even when decomposition of oil proceeds rapidly, the depletion of the oxygen content of the water by the microorganisms degrading the oil may have secondary deleterious ecological effects. Unfortunately, the most readily attacked fraction of crude oil is the least toxic, i.e., the normal paraffins. The more toxic aromatic hydrocarbons, especially the carcinogenic polynuclear aromatics, are not rapidly degraded.

That our coastal waters are not devoid of marine life, after decades of contamination with oil, indicates that the sea is capable of recovery from this pollution. However, increasing stress is being placed on the estuarine and coastal environments due to more frequent oil pollution incidents near shore. Once the recovery capacity of an environment is exceeded, deterioration may be rapid and catastrophic. It is not known how much oil pollution the ocean can accept and recover from, or whether the present rate of addition approaches the limit of the natural system.

There is a dearth of accurate observations on the toxicity of oil to marine organisms. It is difficult to evaluate the toxicity of this complex mixture of compounds which is not miscible with sea water. A variety of techniques have been used which are not intercomparable. In some experiments, oil is floated on the water in the test container, and the concentration given is derived from the total quantity of oil and the total quantity of water. This is clearly not the concentration to which the organism has been exposed. In other experiments, extracts of oil with hot water or with various solvents have been added to the test jar without identification of the oil fraction being tested. In still other cases, care has been taken to produce a fine emulsion of oil in sea water more representative of the actual concentration to which the test organism is exposed. Considering the differences in the meaning of "concentration" in these tests and the variation in sensitivity of the test organisms, it is not surprising that the range of toxic effects that can be found in the literature vary by several orders of magnitude.

Investigation of the toxic biological effects of oil have been reviewed. Toxicity studies by comparable techniques using a variety of marine organisms have been completed. In testing eleven species of phytoplankton, it was found that cell division was delayed or inhibited by concentrations of crude oil (unspecified type) ranging from 0.01 to 1000 ppm. Some copepods were sensitive to a 1 ppm suspension of fresh or weathered crude oil and of diesel oil. The larvae of Balanus balanoides (barnacle) and adult Calanus copepods maintained in a suspension of crude oil ingest, without apparent harm, droplets of oil that later appear in the feces. One hundred percent mortality of developing flounder spawn was found at concentrations of three types of oil ranging from 1 to 100 ppm and an increased abnormality of development at longer periods of time in concentrations as low as 0.01 ppm. In contrast, other experimenters have found that concentrations of several percent are necessary to kill adult fish in a period of a few days.

The evidence is clearer that a combination of oil and detergents is more toxic than oil alone. This was first definitely established in studies of the Torrey Canyon spill. The four detergents tested were all more toxic than Kuwait crude oil, and all showed signs of toxicity between 2 and 10 ppm. The solvents used with these detergents were also highly toxic but tended to lose their toxicity over time through evaporation. A bioassay test was carried out and revealed that the least toxic detergent mixed with oil could be a hundred times as concentrated (1800 ppm) as the most toxic (14 ppm) and cause the same toxic effect.

The toxicity of crude oil has been difficult to interpret since crude oil may contain many different organic compounds and inorganic elements. The composition of such oils may vary from region to region and petroleum products produced can be drastically different in character in line with their different intended uses. The major components of crude oil can be categorized as aliphatic normal hydrocarbons, cyclic paraffin hydrocarbons, aromatic hydrocarbons, naphtheno-aromatic hydrocarbons, resins, asphaltenes, heteroatomic compounds, and metallic compounds. The aromatic hydrocarbons in crude oil appear to be the major group of acutely toxic compounds.

Free oil or emulsions may adhere to the gills of fish interfering with respiration and causing asphyxia. Within limits, fish are able to combat this by defensive mucous secretions. Free oil and emulsions may likewise coat aquatic plants and destroy them.

Fish and benthic organisms may be affected by soluble substances extracted from the oils or by coating from emulsified oils. Water soluble compounds from crude or manufactured oils may also contain tainting substances which affect the taste of fish and waterfowl.

Toxicity tests for oily substances provide a broad range of results which do not permit rigorous safety evaluations. The variabilities are due to differences in petroleum products tested, non-uniform testing proceduures, and species differences. Most of the research on the effects of oils on aquatic life has used pure compounds which exist only in low percentages in many petroleum products or crude oils.

Because of the basic difficulties in evaluating the toxicity, especially of the emulsified oils, and because there is some evidence that oils may persist and have subtle chronic effects, the maximum allowable concentration of emulsified oils should be determined on an individual basis and kept below 0.05 of the 96-hour TL_{50} for sensitive species. TL_{50} is defined as the tolerance limit for 50 percent survival under the specified period of exposure (i.e. 96 hours).

Investigation of the sediments in the Ottawa River in Ohio downstream from a refinery consisted of up to 17.8 percent oil. Sedimented oil has been reported from the Detroit River. It has been reported that the bottom deposits contain 2.5 percent oils in the Illinois River. While the reports may be scattered, the evidence is clear that the existence of sedimented oils in association with oil pollution is widespread.

There is an increasing body of evidence indicating that aliphatic hydrocarbons are synthesized by aquatic organisms and find their way into sediments in areas which have little or no history of oil pollution. Hydrocarbons have been reported in the recent sediments of lakes in Minnesota and the Gulf of Mexico.

Areas which contain oily sediments usually have an impoverished benthic fauna; it is not clear to what extent oil contributes to this because of the presence of other pollutants. However, there are recurring reports of a probable relationship between sedimented oils and altered benthic communities. Sedimented oils may act as concentrators for chlorinated

hydrocarbon pesticides, but the biological implications indicate that additional study is required.

Direct contact by fish (bass and bream) with crude oil resulted in death caused by a film over the gill filaments. Crude oil also contains a water-soluble fraction that is very toxic to fish. Crude oil contains substances soluble in sea water that produce an anaesthetic effect on the ciliated epithelium of the gills of oysters. Free oil and emulsions may act on the epithelial surfaces of fish gills and interfere with respiration. They may coat and destroy algae and other plankton, thereby removing a source of fish food, and when ingested by fish they may taint their flesh.

Settleable oily substances may coat the bottom, destroy benthic organisms, and interfere with spawning areas. Oil may be absorbed quickly by suspended matter, such as clay, and then due to wind action or strong currents may be transported over wide areas and deposited on the bottom far from the source. Even when deposited on the bottom, oil continuously yields water-soluble substances that are toxic to aquatic life.

Films of oil on the surface may interfere with reaeration and photosynthesis and prevent the respiration of aquatic insects such as water boatmen, backswimmers, the larvae and adults of many species of aquatic beetles, and some species of aquatic Diptera (flies). These insects surface and carry oxygen bubbles beneath the surface by means of special setae which can be adversely affected by oil. Oil films on the lower Detroit River are a constant threat to waterfowl. Oil is detrimental to waterfowl by destroying the natural buoyancy and insulation of their feathers.

A number of observations made by various authors in this country and abroad record the concentrations of oil in freshwater which are deleterious to different species. For instance, penetration of motor oil into a fresh water reservoir used for holding crayfish in Germany caused the death of about 20,000 animals. It was established experimentally that crayfish weighing from 35 to 38 g die in concentrations of 5 to 50 mg/l within 18 to 60 hours. Tests with two species of freshwater fish, ruff (small European perch) and whitefish (Family Coregonidae), showed that concentrations of 4 to 16 mg/l are lethal to these species in 18 to 60 hours.

The toxicity of crude oil from various oil fields in Russia varies depending on its chemical composition. The oil used by Veselov (1948) in the studies of the pollution of Belaya River (a tributary in the Kama in European Russia) belongs to a group of methano-aromatic oils with a high content of asphalt, tar compounds, and sulfur. It contains little paraffin and considerable amounts of benzene-ligroin. Small crucian carp (Carassius) 7-9 cm long were used as the bioassay test animal. This is considered to be a hardy fish that easily withstands adverse conditions. The water soluble fraction of oil was extracted by shaking 15 ml of oil in 1 liter of water for 15 minutes. The oil film was removed by filtration. Dissolved oxygen was controlled. A total of 154 tests were performed using 242 fishes. The average survival time was 17 days at the concentration of 0.4 ml/l of oil but only 3 days at the concentration of 4 ml/l. Further increase in concentration had no appreciable effect on fish mortality.

The toxicity of Russian oil is due to naphthenic acids, small quantities of phenol, and volatile acids.

Reports following 96-hour TL_{50} values of naphthenic acid: for bluegill sunfish (Lepomis macrochirus) —5.6 mg/l; pulmonate snail (Physa heterostropha)—6.1 to 7.5 mg/l (in soft water); and diatom (species not identified) —41.8 to 43.4 mg/l in soft water and 28.2 to 79.8 mg/l in hard water. Naphthenic acid (cyclohexane carboxylic acid) is extracted from petroleum and is used in the manufacture of insecticides, paper, and rubber.

Crude oil in concentrations as low as 0.3 mg/l is extremely toxic to freshwater fish. An intensive study of the toxicity of oil refinery effluents to fathead minnows was conducted in Oklahoma. By standard bioassay procedures, mortality varied between 3.1 percent to 20.5 percent after 48 hours of exposure to untreated effluents. They concluded that toxicity rather than oxygen demand is the most important effect of oil refinery effluents on receiving streams.

Oil may injure aquatic life by direct contact with the organism, by poisoning with various water soluble substances that may be leached from oil, or by emulsions of oil which may smear the gills or be swallowed with water and food. A heavy oil film on the water surface may interfere with the exchange of gases and respiration.

A number of observations have been recorded of the concentrations of oil in sea water which are deleterious to various species. Experimental data, however, are scarce and consequently the toxicology of oil to marine organisms is not well understood.

The marine clam (Mya arenaria) occurring on tidal flats of Staten Island, New York, has been destroyed by oil. The Pacific coast sea urchin, Strongylocentrotus purpuratus, dies in about 1 hour in a 0.1 percent emulsion of diesel oil. After 20 to 40 minutes in this concentration, the animals fail to cling to the bottom and may be washed away. Crude oil absorbed by carbonized sand does not lose its toxicity. This has been shown by laboratory experiments conducted at Woods Hole. The amount of oil used was limited to the quantity held in the sand, hence no free oil was present in the water. The oil-sand aggregates were placed in containers filled with sea water but never came into contact with the test animals. Four species were bioassayed: the very hardy toadfish (Opsanus tau) in the yolk sac stage, the moderately tolerant barnacle (Balanus balanoides), the oyster (Crassostrea virginica), and the extremely sensitive hydrozoan (Tubularia crocea). The survival of toadfish embryos was indirectly proportional to the concentration of oil in water. In a concentration of 0.5 percent, the embryos survived for 13 days (end of test); in 1.25 percent, 8 1/2 days; in 2.5 percent, 6 days; and in 5 percent, 4 1/2 days. Barnacles suffered 80 to 90 percent mortality within 70 hours in 2.0 percent mixtures of oil in sea water. They became inactive in 23 hours in concentrations of 2 percent and above. Tubularia suffered 90 to 100 percent mortality within 24 hours after being placed in water containing a 1:200 oil-carbonized sand aggregate. Water extracts of crude oil were lethal within 24 hours of concentrations of 500 mg/l and greater. Experiments with oysters consisted

primarily of determining the effect of oil adsorbed on carbonized sand, on the number of hours the oysters remain open and feeding, and on the rate of water transport across the gills. A paste-like aggregate of oil in carbonized sand (50 ml crude oil to 127 g sand) was prepared, wiped clean of excess oil, and placed in the mixing chamber. Sea water was delivered through this chamber to the recording apparatus at a rate slightly in excess of the rate of water transport by oyster gills. There was a noticeable decrease in the number of hours the test oysters remained open and in the daily water transport rate through the gills. The time open was reduced by 95 to 100 percent during the first 4 days of testing to only 19.8 percent on the 14th day. The total amount of water transported per day, presumably used for feeding and respiration, was reduced from 207 to 310 liters during the first 6 days to only 2.9 to 1 liter per day during the period between the eighth and fourteenth day of continuous testing. These tests indicate that oil incorporated into the sediments near oyster beds continues to leach water-soluble substances which depress the normal functions of the mollusk.

Critical observations are lacking on the effect of oil on pelagic larvae of marine invertebrates, but there is good reason to assume that crude oil and petroleum products are highly toxic to free-swimming larvae of oysters. They are killed by contact with surface oil film. Laboratory experience shows that oyster larvae from 5 to 6 days old were killed when minor quantities of fuel oil were spilled by ships in the harbor at Woods Hole and the contaminated water penetrated into the laboratory sea water supply.

The tests described above leave no doubt that water-soluble substances are leached from oil spilled into water and adversely affect marine life. It is reasonable to assume that the water soluble materials of oil may contain various hydrocarbons, phenols, sulfides, and other substances toxic to oyster larvae.

Effects of Treated Oils

Studies of the primary productivity and community respiration in a series of oil refinery effluent oxidation ponds have shown that there are detrimental effects on the biota. These ponds received wastewaters which had been in contact with the crude oil and various products produced within the refinery. In a series of oxidation ponds, primary productivity and community respiration measurements clearly indicated that primary producers were limited in the first ponds, probably by toxins in the water. Oxidation ponds further along in the series typically supported algal blooms. Apparently biochemical degradation and physical weathering of the toxic organic compounds reduced their concentration below the lethal threshold to the algae. Primary productivity was not greater than community respiration in the first ponds in the series. It was also shown that species diversity of phytoplankton was lowest in the first four ponds of the series of ten. A "slug" of unknown toxic substance drastically reduced the species diversity in all ponds. Zooplankton volumes increased in the latter half of the pond series, presumably as a result of decreasing toxicity. Benthic fauna species diversity in streams receiving oil refinery effluents was low near the outfall and progressively increased downstream as biological assimilation reduced the concentration of toxins.

Long-term, continuous-flow bioassays of biologically treated oil refinery effluents indicated that complex refineries produce effluents which contain cumulative toxins of substances that cause accumulative deleterious effects. Subsequent long-term continuous-flow bioassays of biologically treated oil refinery effluents indicated that passage of the effluent through activated carbon columns does not remove the fish toxicants. Of the fathead minnows Pimphales promelas tested, half were killed in 14 days, and only 10 percent survived 30 days. Trace organic compounds identified in extracts from the effluent were a homologous series of aliphatic hydrocarbons ($C_{11}H_{22}$ through $C_{18}H_{38}$) and isomers of cresol and xylenol. Since the soluble fractions derived from oil refineries are quantitatively, and to some extent qualitatively, different from those derived from oil spills, care must be taken to differentiate between these two sources.

Presence of hydrocarbons similar to benzopyrene in oil-polluted coastal waters and sediments of France in the Mediterranean have been reported. The effluents from the industrial establishments on the shores at Villefranche Bay comprise tar substances, which contain bensopyrenes, benzo-8, 9-fluoranthene, dibenzanthracenes, chrysene, 10-methyl anthracene, and nitrogenous derivatives such as dimethylbenzacridine. These substances are carried out into the bay water and settle on the bottom. The pollution is augmented by incompletely burned oils discharged by turbine ships. The content of benzopyrene in bottom sediments ranges from 500 micrograms in 100 g samples collected at the depth of 8 to 13 cm to 1.6 micrograms at 200 cm. Similar contamination is of importance in the Gulf of Fos, Etang de Berne, and in the delta of the Rhone River.

Carcinogenic Effects

Carcinogenic hydrocarbons were found to be stored in plankton of the Bay of Villefranche in concentrations varying from 2.5 to 40 micrograms per 100 g. Fixation of benzopyrenes were found also in the bodies of holothurians in a bay near Antibes. The reported concentration in the visceral mass of a holothurian was slightly higher than that in the bottom sediment.

Observations on storage of carcinogenic compounds found in oil-polluted water are biologically significant. The important question of biological magnification as these compounds are ingested by plankton feeders remains unanswered and needs to be investigated.

Public Water Supply Effects

It is very important that water for a public water supply be free of oil and grease. The difficulty of obtaining representative samples of these materials from water makes it virtually impossible to express criteria in numerical units. Since even very small quantities of oil and grease may cause troublesome taste and odor problems, none of this material should be present in public water supplies. An additional problem attributable to these agents is the unsightly scumlines on water treatment basin walls, swimming pools, and other containers.

Waterfowl and Wildlife Effects

Waterbirds, muskrats, otters, and many other wildlife species require water that is free of surface oil. Egg laying has been inhibited when mallards ingested small quantities of oil. When oil from the plumage was coated on mallard eggs, it reduced hatching from 80 to 21 percent. The full significance of this type of damage to wildlife populations is unknown.

Dramatic losses of waterbirds (ducks, geese, coot, swans, gannets, murres, and others) result from contamination of the plumage by oil from the surface of the water. Once the birds plumage is soaked with oil, the bird loses its natural insulation to the cold and dies. Many hundreds of thousands of birds have died from oil pollution in some years in North American waters.

Oil that settles to the bottom of aquatic habitats can blanket large areas and destroy the plants and animals of value to waterfowl. Reportedly, some oil sludges on the bottoms of aquatic habitats tend to concentrate pesticides, thus creating a double hazard to waterfowl that would pick up thse contaminants in their normal feeding process.

The death of marine birds from oiling is one of the earliest and most obvious effects of oil slicks on the sea surface. Thousands of seabirds of all varieties are often involved in a large spill. Even when the birds are cleaned, they frequently die because the toxic oil is ingested in preening their feathers. Frequently, dead oiled birds are found along the coast when no known major oil spill has occurred; and the cause of death remains unknown.

The mortality of seabirds as a result of oil pollution is direct and immediate, and in a major oil spill, is measured in the thousands. The diving birds which spend most of their life at sea are most prone to death from oil pollution, but any bird that feeds from the sea or settles on it is vulnerable. In oil-matted plumage, air is replaced by water causing loss of both insulation and buoyance. Oil ingested during preening can have toxic effects.

Oil has been fed directly to birds by stomach tube and the pathological and physiological effects later analyzed through autopsies. The lethal dose for three types of oil ranged from 1 ml to 4 ml per kilogram (ml/kg) when the birds were kept outdoors under environmental stress. The experimenters concluded that a duck could typically acquire a coating of 7 grams of oil and would be expected to preen approximately 50 percent of the polluting oil from its feathers within the first few days. Enough of this could easily be ingested to meet the lethal dosage of 1 to 4 ml/kg. Thus, birds that do not die promptly from exposure to cold or by drowning as a result of oil pollution may succumb later from the effects of ingestion.

Pollution in Media Other Than Water

Since Public Law 92-500 involves water pollution legislation and Section 104(m)(1)(B) requires studies of long-term chronic biological effects of waste oils, the effects on freshwater and marine biota are discussed in Section D above. The foregoing is not to be construed as saying there are no other biological effects of disposal of waste oils. This is an extremely important point when the engineering scientists are asked to devise methods to further reduce the input of waste oil into the waters of the United States. The proposed methods and new technology development must still address the issue of final placement of the toxic substances in our environment; i.e., land disposal, recycling, and fuel consumption. Specialists in air pollution, land waste disposal, and terrestrial ecology are in the best position to take the lead in answering these environmental questions. They should, however, coordinate their recommended activities with aquatic biologists and aquatic ecologists.

Recommendation

In view of available data, it is concluded that to provide suitable conditions for aquatic life, oil and petrochemicals should not be added in such quantities to the receiving waters that they will: (1) produce a visible color film on the surface, (2) impart an oily odor to water or an oily taste to fish and edible invertebrates, (3) coat the banks and bottom of the watercourse, or (4) taint any of the associated biota.

Oil is an especially dangerous substance to waterfowl. Oil and petrochemicals must be excluded from both the surface and bottoms of any area used by waterfowl.

The only effective measure for control of oil pollution (crude, refined, waste oil) in the aquatic environment is prevention of all spills and release. The time-lag involved in corrective methods means that some damage will inevitably occur before the corrective measures take effect. Furthermore, the soluble parts of the oil already in the water will not be removed by any of the presently known methods of post-spill cleanup.

In the final report, we intend to address the following questions:

1. In regard to land application:

a. Do the altered (used) hydrocarbons act similarly to crude or refined hydrocarbons; i.e., are they biodegradable?

b. What levels of heavy metals can be tolerated on or in the land?

c. What will be the effect on ground water?

d. What will be the effect on surface runoff water quality?

2. In regard to consumption as an additional fuel source:

a. Can the economics and engineering requirements be resolved to meet the secondary air quality standards for heavy metals?

b. What is the effect of these yet undetermined heavy metals (found in waste oil) emitted from smoke stacks on terrestrial flora and fauna?

c. What is the effect of combustion of waste oils on the user equipment?

E Economic and Legal Aspects of Waste Oil Policy

Section 104(m)(1)(c) of the Federal Water Pollution Control Act Amendments of 1972 require the Administrator of EPA to study "...the potential market for such oils, including the economic and legal factors relating to the sale of products made from such oils, the level of subsidy, if any, needed to encourage the purchase by public and private nonprofit agencies of products from such oil, and the practicability of Federal procurement, on a priority basis, of products made from such oil." As described in the next section of this report, "Additional Information Being Developed," EPA is now initiating research studies to obtain the necessary information for inclusion in its Final Report to Congress on Waste Oil due in April 1974.

Since most of the research described in the next section is just starting, this preliminary report does not contain a detailed description of the current waste oil problem; nor does it discuss the advantages and disadvantages of alternative policies for addressing the problem. Such a discussion would be premature at this time. The discussion which follows in this section merely describes the general economic and legal nature of the waste oil problem, and the principles which EPA has followed in designing the studies now underway.

As stated in previous sections, a large amount of waste oil is unaccounted for each year and probably is disposed of in the environment. It is believed that waste oil dumping into the environment is practiced by households, industrial firms, gas stations and garages, waste oil collectors, and even by more waste oil recovery firms. Since this dumping is usually illegal, it is impossible to obtain reliable information on the quantities and locations of dumping.

If waste oil had a high economic value for use not involving environmental damage, there would be little need for a governmental role in this field. The oil would be transported through a series of profitable transactions to its new use. Unfortunately, the waste oil recovery business has declined over the past decade. One task of the EPA studies is to identify the specific causes for that decline and to make projections of the future prospects for the industry. In order to prepare for all contingencies, EPA is studying a broad range of alternatives for resource recovery and less damaging environmental disposal.

As touched upon before in this report, the waste oil problem is the sum of many diverse and complex sub-problems; many different types of waste oil, many alternative modes of disposal into the environment, many alternative modes of waste oil recovery, alternative incidences of legal liability for disposal or recovery, and alternative incidences of cost burden for disposal or recovery. A subject of this complexity requires an organizing framework to guide the many individual studies underway. To supply a cohesive framework for further research, EPA is using the following ten working principles:

1. The costs of reducing environmental damage from waste oil should be borne directly by the parties creating the problem, that is, by those who produce, consume, and dispose of waste oil. Such cost internalization may cause minor readjustments in relative prices. Such an outcome is consistent with the policies expressed by the President in his Environmental Messages.

2. Some reduction in environmental damage from waste oil may be achieved by just changing the mix of environmental disposal modes used. Some disposal modes are less damaging than others. Certain disposal modes may have to be prohibited.

3. There is not one form of waste oil recovery which is environmentally superior in every circumstance. Waste oil recovery operations have complex environmental impacts involving interpollutant and intermedia tradeoffs. A resource recovery alternative which would be superior to another under one set of environmental conditions might well be inferior under a different set of conditions. This makes it highly improbable that the Environmental Protection Agency will ever find one recovery alternative to be preferred and stimulated under all conditions.

4. When users of waste oil wish to take efforts on their own part to reduce the environmental damage associated with waste oil, facilities should be provided to make these efforts inexpensive and convenient for them.

5. There are probably wide differences in the amount of environmental damage caused by waste oil in different parts of the country. Different communities probably also have different conceptions of the size of benefits to them from reducing waste oil disposal into the environment. To the extent possible, these differences should be reflected in policies chosen to deal with the waste oil problem.

6. All waste oil recovery operations now operate under non-market constraints which impede the expansion of their production relative to the production of oil products from virgin oils. Among these constraints are the depletion allowances enjoyed by producers of virgin oil products, various labeling practices and regulations, treatment of waste products in rate-setting by the Interstate Commerce Commission, and features of the Internal Revenue Code which discourage the use of recycled oil by off-road users. Since most of these constraints emanate from Federal law or regulation, the Environmental Protection Agency is intensively studying their effects.

7. In comparing resource recovery alternatives, it is important to consider the performance characteristics of the recovery product. The length of product life, for example, is important in determining both the economic attractiveness and environmental impact of the recovery product. Product life and other performance characteristics are also being evaluated in relation to Federal procurement policy.

8. Waste oil policy should be examined as a component of total environmental policy. Waste oil policy should be compatible with other policies concerning disposal of hazardous materials and regulations covering prevention of oil spills. The legal aspects of analogous waste oil approaches are now under study. The impact of sulfur oxide emission controls on the demand for recovered waste oil as a blended fuel oil in electric power plants is also being studied.

9. In considering waste oil policy options, it should be recognized that State and local governments may have different and original approaches. They may also have special legal or administrative capabilities to offer in resolution of the problem.

10. The experience of other industrialized nations in dealing with waste oil problems offers value insights. Comparison of the legal approaches taken in different countries is part of planned EPA research.

It should be emphasized that the above list of working principles does not represent any firm policy conclusions, but merely guidance for research in progress. Discussion of specific policy options is deferred until the final report.

F Additional Information Being Developed

Due to the time limitations imposed for the submission of this preliminary report, it was not possible to obtain and analyze sufficient data on many aspects of the waste oil problem. A concerted effort is now underway to provide the necessary information in sufficient time to allow its inclusion in the final report which will be submitted about one year from now. These efforts include the following:

1. Technology Development and Effects Research

A project currently underway for the development of a process for the production of a salable re-refined material will be completed. If successful, this process will provide the technology required for the re-refining of waste oils from all sources economically. We realize that the project now underway is only one possible re-refining technique and we, therefore, plan to study other processes which might be applicable. In addition, the grant which was made to the State of Maryland will develop a collection and disposal plan for that State. This data will be extrapolated to allow its use in other parts of the Nation. An additional study will be undertaken to obtain data on the quantity and quality of waste oil feed stocks, the processes now employed for re-refining and the economics of these processes, the present disposal practices and environmental impact of these practices, and a material balance of waste oils produced and disposed of. The ecological effects of waste oils on marine and fresh water species will be studied.

2. Economic Study on Factors Affecting Waste Oil Re-Refining

The basic objective of this study is to prepare a Federally based strategy that will promote and encourage recovery or disposal of waste lubricating oil in an environmentally sound manner. The research emphasis will be on waste oil re-refining. In this study, the following aspects will be considered:

(a) identification of current and potential processes utilizing waste oils

(b) environmental analysis of the process

(c) analysis of economic and marketing constraints and institutional barriers to increased marketing of products containing waste oil

(d) analysis of various strategies to overcome these constraints and barriers

Among the strategies to be considered are Federal procurement, fiscal and regulatory measures.

3. Study of the Factors Affecting the Use of Waste Oil as a Blended Fuel Oil in Streampower Plants

This study will collect information on the factors affecting the industrial demand for blended waste oil. Particular emphasis will be given to steam power plants. Evaluation will be made of the repair and downtime costs associated with given types of pretreated waste oil, given technologies employed in the power plant, and given grades and proportions of other fuel oil used for blending. Information will be obtained on the total impact of environmental restrictions (particularly restrictions on sulfur oxide emissions) on the relative competitiveness of ordinary fuel oils and blended waste oils. Information will also be obtained on the technological and economic factors which determine the profitability of given types of waste oil pretreatment operations.

4. Study of Alternative Legal and Economic Institutions used to Deal with the Waste Oil Problem

There is a wealth of accumulated experience in other industrialized countries on regulatory and economic incentive approaches to the waste oil problem. The successes and failures of these systems can provide valuable input to policy discussion in this country. This study will compare the systems in operation in other countries with the systems in use and under consideraion in the U. S. This will involve a mixture of legal and economic analysis. The study will also explore the question of what legal approaches to waste oil would be most compatible with current and proposed regulation of other hazardous substances.

5. Miscellaneous Studies

It is recognized that a sizeable percentage of the waste oils produced originate with the home user and the farm user. A study will, therefore, be undertaken to determine how this waste oil should be handled and what effect its disposal has on the environment. In addition, it is recognized that the wastes produced in ballast and bilge tanks aboard ships are unique in nature. A study will be made on the best method to collect and separate these wastes without causing enviromental damage.

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